LOCAL ANESTHESIA

ITS

SCIENTIFIC BASIS AND PRACTICAL USE

BY

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SECOND AMERICAN FROM THE SIXTH REVISED GERMAN EDITION

WITH 231 ILLUSTRATIONS IN BLACK AND COLORS

LEA & FEBIGER
PHILADELPHIA AND NEW YORK
1924

PRINTED IN U. S. A.

PREFACE TO THE SECOND ENGLISH FROM THE SIXTH GERMAN EDITION.

Braun's "Local Anesthesia" has been the standard work on this subject since the appearance of the first edition in 1905. Nearly everyone who has written on the subject since that time has drawn largely on the fund of information contained in this work, the great popularity of which is well shown by the fact that it has passed through six editions. The third edition was translated into English in 1914, in order that it might be available to those who were unable to read it in the original. Since then there have appeared the fourth, fifth and now the sixth editions. The sixth edition contains so much new matter and so much of the old has been rewritten in the light of more extended experience that the need of an entirely new translation was evident. In the translation an endeavor has been made to adhere strictly to the text except where the Editor's notes clearly indicate to the contrary. It is hoped that the translation will receive the same favorable reception that has always been accorded the original.

M. L. H.

Chicago, 1924.

AUTHOR'S PREFACE TO THE SIXTH EDITION.

In the hope that it will be of advantage to the reader I have again thoroughly revised Chapter VI on Lumbar and Sacral Anesthesia, besides adding more recent experiences throughout the text. Novocaine poisoning has been treated more extensively. I have endeavored to outline more clearly the indications, contraindications, and limitations of local anesthesia. Finally, it has been necessary to abridge the constantly increasing bibliography by omitting the older references which did not have a distinct historical interest. I believe that the value of the work has not been diminished thereby.

Prof. Dr. H. Braun.

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LOCAL ANESTHESIA.

CHAPTER I.

HISTORY OF LOCAL ANESTHESIA UP TO THE DISCOVERY OF COCAINE.

THE most important step in the development of modern surgery, following the antiseptic or rather aseptic treatment of wounds, has been the possibility of operating without pain. The danger and pain, together with most uncertain final results following the slightest surgical procedure, were the heavy responsibilities imposed upon the science of surgery in early days. The attempts to improve upon the treatment of wounds was like groping in the dark, so long as the cause of wound infection and the methods of overcoming it were unknown. The ways of relieving the patient from surgical pain were far more clearly defined. The desire to relieve pain is as old as the history of man but its consummation was long delayed. For many centuries there existed an unending difference between desire and attainment which found expression in the words of Hippocrates, *Divinum est opus sedare dolorem.* It was recognized in the countless mistakes made in the attempts to attain the goal and caused Velpeau, more than two thousand years after Hippocrates, only shortly before success was attained, to express himself in these disconsolate words: *Eviter la douleur dans les opérations, est une chimère, qui n'est pas permise de poursuivre.* The oldest written traditions that we have relate of attempts to produce artificial sleep: Egyptian, Chinese, Greek and Roman physicians and medical men of African natives (Felkin) were acquainted with the narcotic properties of the juices of certain plants and used them in the form of drinks to relieve the pain of patients undergoing surgical operations. Alcohol was also used for many years for this purpose.

During the Middle Ages narcotic inhalations were used in the effort to produce general anesthesia. Sponges soaked in the juices of the miracle-producing mandrake root, hemlock, henbane, and poppy, so-called sleep sponges, were used to convey the vapors of various plant juices to the patient to induce sleep. These were the only means at the disposal of the surgeons in this early period. The older methods of narcosis were too dangerous when effective and too ineffective when free from danger. There is no doubt that life is endangered if a patient is so benumbed with alcohol, opium, cannabis indica, etc., that the sense of pain during operation

is lost. On the other hand, we know that a semiconscious patient does not withstand operation so well as one fully conscious, and resists the efforts of the surgeon more than the latter. For this reason narcosis by this method was rarely used toward the end of the Middle Ages, and later on was entirely given up by the surgeons.

By means of various precautionary methods, some fantastic, some useful, attempts were made to lessen the pain and shorten its duration which must now be looked upon as a step in the advancement of knowledge. We learn that greased and warm instruments should lessen pain in cutting through tissues, in fact the same virtues were ascribed to golf and silver instruments. Skill and speed on the part of the operator materially shortened the suffering of the patient, and these were made possible by the development of operative technic and improvement in the surgical armamentarium.

It is interesting to note that Lisfranc advised, whenever possible, to cut the nerves supplying the operative field with the first incision. The history of general anesthesia began with the discovery of modern inhalation anesthetics, as nitrous oxide, ether, chloroform, and ethyl bromide; and until that time no great improvement was made.

Just as old as the attempts to use narcotics were the attempts to relieve surgical pains by local means. According to the statements of writers of ancient and medieval times, Egypt is said to have possessed two such agents. The one taken from the holy animal of the land consisted of the fat of the crocodile or the dried and powdered skin of the same animal. This was to be laid on the skin of the patient and was supposed to induce anesthesia. We will make no mistake in classing this with the religious and mystic ceremonies underlying suggestive therapy of the old as well as present times. The other supposed Egyptian agent is the oft-mentioned stone of Memphis, which, according to Plinius, produced local anesthesia if rubbed on the skin with vinegar. During the Middle Ages this method was wrongfully considered a means of inducing general anesthesia. From present sources of information we are unable to state what this stone was. Littré has suggested that this stone was a variety of marble which, when used as before mentioned, evolved carbon dioxide. Opposed to this theory is the fact that carbon dioxide has no influence on the intact skin. Huseman holds in reference to the traditional statements of Pliny and Dioskorides that it is doubtful if a "Lapis Memphitis" was actually used for purposes of local anesthesia in ancient times, as the translation of the old Egyptian medical works do not mention definitely anything regarding this stone.

Of greater historical importance is the fact that already in ancient times a method of producing local anesthesia was discovered, namely, the compression of the nerve trunk. This accomplished its purpose without doubt to a certain degree, and one was actually able by this means to perform operations upon the extremities, namely, amputations, with little if any pain, even if the pain occasioned by the operation was only exchanged for the pain caused by the compression. This form of anesthesia is being

constantly brought up anew after all other methods are abandoned or forgotten, only to be again given up on account of its serious after-effects. The observation that patients with neuralgia and other painful affections instinctively tried to lessen their pain by pressure upon the affected parts, also that paralysis occasionally followed accidental pressure on the nerve trunks; and, again, the binding of a limb to prevent hemorrhage during amputations, causing disturbances of sensation, were possibly the reasons for popularizing this method. According to the investigations of Corradis, the binding of an extremity with a band for the purpose of producing local anesthesia was in use since the classical times. The Arabian physicians likewise used a method of ligating a limb with the aid of a stick, not only to prevent the loss of blood but also to reduce pain. In the sixteenth century Ambroise Paré used this method for a like purpose. In 1676 Schumann described the amputation of a leg of a woman under local anesthesia, praising the "ligatura fortis" both for its blood-stilling and pain-reducing qualities. While the medical onlookers observed the amputated foot and the wound surgeon busied himself tying up the part, the woman asked: "Is the foot already off?" She rejoiced to hear that all was over.

Van Swieten and Theden advocated interrupted compression of the entire surface of the limb by means of strong bandages. Juvet again advocated the circumscribed ligation of a limb above the field of operation and held this method to be sufficient in preventing all sensation. On account of many failures and the opposing statements from authoritative sources this method again fell into discredit. De Sault said that in his time (beginning of last century) this method was in general use, but he gave it up as the ligation of an extremity carried with it the danger of gangrene if tied sufficiently tight to produce anesthesia. Thirty years later, in spite of these statements, Liégard again used this procedure and described several toe operations performed without pain after tying off the leg just above the ankles. Velpeau also recommended this method, having gained his experience in operating on the great toe. This method seems never to have been given recognition in Germany. In England, J. Moore, in 1784, attempted to bring about pressure paralysis of the sensory nerves by other means. He constructed an apparatus with two pads, one to compress the sciatic nerve and the other the anterior crural. He describes a leg amputation which was carried out in this way without pain, after the apparatus had been in place for one and a half hours, during which time the patient received 1 grain of morphine. Hunter, who witnessed this operation, recommended Moore's method, also B. Bell, who in fact stated that it was the only remedy suitable for the lessening of operative pain. Other surgeons had no success with this method. Malgaigne tried brisement forcé on the knee-joint with the help of Moore's apparatus, but it was found necessary to interrupt the operation, as anesthesia was not obtained. This apparatus was found to be defective, as it caused very severe pain and intense venous congestion in the limb to which it was applied. A sufficient compression of the crural nerve was

impossible for anatomical reasons, therefore Moore's method was soon forgotten and replaced by the simpler method of ligation. In the early seventies of the last century compression or ligation anesthesia was again tried by surgeons of all lands from both a theoretical and practical standpoint, following the introduction by Esmarch of his rubber bandages in bloodless surgery, and even in more recent times was again advocated.

Long after compression another remedy, also physiological, for the local relief of pain, was used for surgical purposes, namely, cold. This was first introduced about the middle of the sixteenth century by Thomas Bartholinus, who learned of the pain-stilling quality of cold from his teacher, Marco Aurelio Severino, the Neapolitan anatomist and surgeon.[1]

His recommendations were later forgotten, three hundred years passing before the chilling of the tissues was again used in surgery, notwithstanding repeated observations made with this agent. J. Hunter found by animal experimentation that the ears of rabbits became insensible when surrounded by a freezing mixture. Larrey, chief surgeon to Napoleon's army, relates that the wounded in the battle of Eylau (February 7–8, 1807) requiring amputation had absolutly no sensation in their limbs, the operation being performed with the temperature 19° below zero. Another French military surgeon, Moricheau-Beaupré, who served under Napoleon during the Russian campaign, remarked about the sedative action of cold, but mentioned no specific instance in which cold was used as an anesthetic. The chilling of the tissues for inducing anesthesia was described by Arnott (1848), Guérard, Richet (1854), and introduced practically by Richardson. It is useful today in minor surgery and is a helping agent with other anesthetics.

We have to go back into the oldest times if we wish to follow up the experiments which were made to produce local anesthesia by chemical agents, particularly of vegetable origin. At the end of the eleventh book of the Iliad it is related how Patroclus cut an arrow from the back of the wounded Euripides:

> "And there Patroclus laid him down and cut
> The rankling arrow from his thigh, and shed
> Warm water on the wound to cleanse away
> The purple blood, and last applied a root
> Of bitter flavor to assuage the smart,
> Bruising it first in his palms: the pangs
> Ceased; the wound dried; the blood no longer flowed."

The idea which prevailed up to the present time that narcotic remedies must produce their peculiar effect when applied locally has been the stimulus which led to the attempts to produce local anesthesia. In

[1] Thomas Bartholinus states: Antiquam cauterio ulcera in membris excitentur, nix affricata induit stuporem. Id me docuit Marcus Aurelius Severinus in Gymnasio Neapolitano olim preceptor meus et hospes, Chirurgorum hoc saeculo princeps. Rectissime autem nivem in vasculum materiæ convenientis capax, sed oblonga ad extremum et myrtiformi specie, conjectam, sine rei ullius interventu applicavit. A gangrenæ metu securos non jussit, medicamento sub angustis parallelis lineis applicato, sensu vero post horæ quadrantem sopito, secare locum indolentem licebit. (Cited by Kappeler.)

ancient times mandragora, hyoscyamus, aconite, and juice of the poppy seed and Indian hemp were in almost universal use by the Hindus, Egyptians, Greeks and Romans in the preparation of pain-quieting applications, plasters, salves, washes, etc. These probably were used more by the magicians and quacks than by the physicians, and were also used less as a prophylactic against operative pain than for the relief of painful afflictions. The old Egyptian physicians knew (Prosper Alpin) that mixtures of benumbing substances could produce local anesthesia for surgical purposes. It is indeed interesting to note that the Chinese even in recent times (Porter Smith), after the discovery of chloroform and the knowledge of its use, applied such artemisian mixtures for local anesthesia as the datura tatula, cannabis indica, atropa, and mandragora, drugs described in Pen-t' san-Kong-muh by Li-shi-chin in 1597, the date of the earliest materia medica. The leaves of these mixtures were made into balls with calamus leaves, placed on the painful areas or operative field and burned. This artemisia was so highly prized by the Chinese that with the defeat of their fellow tribesmen, the south Asiatics in Borneo, they were compelled to pay tribute in artemisian camphor (Koehler).

In the middle ages we again meet with the local use of narcotic drugs for the relief of pain in surgical operations. The local use of these drugs originated in the medical school of Salerno, which was the first to use narcotic inhalations for similar purposes. Ægidius von Corbeil, a well-known professor at Salerno, states that about the middle of the twelfth century, by the use of cataplasms of poppy, henbane, and mandrake root applied to the skin, the field of operation could be rendered insensitive.[1]

It is hard to believe that by these means a sufficient amount of the previously mentioned drugs could be absorbed from the unbroken skin to produce a useful anesthesia. This method was not more generally accepted than the oldest anesthetic procedures. In more recent times (1850) we have evidence of similar experiments by Bouisson, who describes an operation for unguis incarnatus, which he was able to perform without pain, after bandaging the toe for several days with applications containing opium. The same idea that remedies which were useful in the artificial production of sleep must be likewise of use for local anesthesia if applied to the skin is once again noted after the introduction of ether and chloroform anesthesia. This was most strikingly stated by Richardson, who claimed that general and local anesthesia were identical processes brought about by the dehydration of the tissues. Expression was again given to these views in a quotation by Arans: "Que toutes les substances, volatiles, auxquelles on a reconnu jusqu'à ce jour des propriétés anesthésiques générales, possédent également des propriétés anesthésiques locales, ou en application intérieur, ou sur la peau."

Indeed, this property seemed more likely to pertain to the volatile

[1] De Renzi, Coll, Salernit., cited by Husemann: Est quoque notandum, quod papaver, jusquiamus mandragora plurinum somnum provocant, unde pro sua nimia humiditate, si ex his fiat cataplasms et ponatur loco de quo debet fieri incisio, vel cyrurgia, omnino removebit sensibilitatem.

inhalation agents as they are capable of penetrating the skin relatively easily as Parisot demonstrated for choloroform. The truth of this statement has been verified only to a limited extent. Some of these substances when used in a gaseous or fluid state on the skin produce, after more or less severe irritation or destruction of tissue, superficial and fleeting disturbances of sensation even when the effect of cold from evaporation is prevented. Simpson, Nunnelly, Aran, and later Kappeler, convinced themselves of the efficiency of chloroform as a local anesthetic notwithstanding its irritating properties. Extensive experiments by Wittmeyer demonstrated conclusively that local anesthesia could be produced with liquor Hollandicus (ethylenchloride) and ether hydrochloricus chloratus (a mixture of tri- and tetra-chlorethylchloride). Experiments along these same lines had already been carried out by Wutzer, Aran, and Nunnelly. Other inhalation anesthetics like ether sulphuricus and amylen were ineffective when applied to the skin. Corning, in later experiments, was unable to produce local anesthesia under any circumstances with chloroform, while Bumm, after trying the preparations recommended by Wittmeyer, found the relief from pain so fleeting and incomplete that the anesthesia was insufficient for the most superficial or shortest surgical operation. These experiments were barren of practical and useful results and have for us about the same historic interest as the cataplasms of the professor of Salerno.

Other agents and methods, some even of a peculiar kind, should be considered in a similar manner. Their use and recommendation sprang from an earnest desire for a practical method of local anesthesia, but in general were only recognized by their inventors. Some of the same, for the sake of completeness, should be mentioned here. An experiment with one of these reputed agents has been described by Simpson and Nunnelly, who stated that prussic acid was the best local anesthetic, a belief shared by many others, notwithstanding the fact that no one carried out an experiment to prove the truth of this assertion. Simpson tried the method by placing his finger in a glass containing prussic acid, but on account of alarming toxic symptoms was compelled to discontinue the experiment. Percival in 1772 discovered that under certain conditions CO_2 could be used as a local anesthetic. Later, Ewart and others advised the use of carbonic acid in the form of a spray in cases of painful ulcers. In 1774, Ingenhous and Beddoes demonstrated experimentally the sedative effect of carbonic acid on parts of the body from which the epidermis had been artificially removed. Broca and Skinner tried this method with success in painful affections of the bladder, and Simpson, Follin, Scanzoni, Maisonneuve, Monod, and Demarquay in diseases of the female genitalia and various surgical conditions. All observers agreed that carbonic acid applied to the intact skin produced no anesthetic effect, for which reason it was very seldom used in operative work.

As an oddity we might mention here that Guerin suggested the burning of a small strip of skin around the field of operation with Vienna paste in order to render it insensitive, and claims to have removed a breast in

this way, supposedly without pain, and he recommended the method to others. Strange as it may seem, this method was advocated not during the Middle Ages but in the year 1883.

The results of the simple superficial application of volatile liquids to the skin for the purpose of inducing anesthesia were up to this time very unsatisfactory and impractical. Richardson now advocated the use of the electric current in aiding the absorption of these agents to which anesthetic properties had been ascribed. In short, from numerous observations it was thought that the galvanic and faradic currents were alone capable of producing local anesthesia. On the advice of Francis, a dentist from Philadelphia, Rottenstein, Suerssen and many others carried out experiments for the painless extraction of teeth, using electric currents. Foussagrives, Bygrave, Friedrich and Knorr used this method for similar purposes in performing other minor operations. Their results were lauded with enthusiasm, notwithstanding the fact that Nussbaum, von Bruns, Bumm and others had proved the absolute uselessness of the method. We know today without doubt that neither the induced nor constant current has any effect in the production of local anesthesia which would be of use in minor surgical work. Bumm has said: "The very conflicting statements of various authors would be difficult to explain, were it not for the fact that one must always remember the self-delusion of the operator on the one hand and the varying or even untruthful statements as to subjective feeling on the part of the patient on the other." This statement is certainly true, for everywhere in the history of local anesthesia the role of suggestion and auto-suggestion is found playing a large part. No matter how imperfect a method of local anesthesia may be, it will still have its adherents. The same state of affairs is occasionally found even today.

Richardson's "Voltaic Anesthesia" consisted in the application of the positive electrode of the galvanic current to the skin, the sponge of the electrode being wet with the solutions of the tincture of aconite, extract of aconite, and chloroform. He conceived the idea that the circulation in the part to be anesthetized would be increased in rapidity from the irritation of the galvanic current, and would therefore be better fitted for the absorption of the narcotic drug with consequent anesthesia. The control experiments of Wallers proved that the slight insensibility of the skin produced by this means, even with the accompanying severe irritation, was due to the drug itself and was in no wise dependent upon the electric current. Much later (1886) Adamkiewicz tried to aid the absorption of chloroform by the skin with the cataphoric action of the electric current. Paschkis and Wagner, and later J. Hoffmann, demonstrated that cataphoresis did not occur with the electric current used in connection with the non-conductor chloroform. In regard to the newer and more fruitful efforts with cataphoresis, see Chapter IX.

Anesthesia of mucous membranes by means of local applications seems to have been little, if at all, attempted in former medical times, although more should have been expected from these tissues on account of their greater permeability than from the intact skin. Carbonic acid had been

used for purposes of local anesthesia as previously mentioned, and seems to have been applied to the mucous membranes of the mouth, pharynx, bladder and female genital organs. In more recent times Brown-Séquard mentioned that the larynx could be made absolutely insensitive by allowing a stream of carbonic acid gas to play against the back part of the throat for a few minutes. Gellé used with success applications of CO_2 gas to the external ear for relieving earache. Attempts at producing local anesthesia of mucous membranes by the vapor of ether or chloroform have been occasionally noted in the literature, but the extensive use of this method never found general acceptance. The discovery of the laryngoscope in 1857, and with it the development of laryngology, brought about a most urgent need for a means of anesthetizing the mucous membrane of the larynx. In the year 1862, Lewin made the statement that a drug for producing local anesthesia of the larynx did not exist. Huette and Czermak recommended potassium bromide for the larynx, but their results could not be verified by Lewin, Scheff, and others. The results of Tuerck, Bruns and Schroetter, and later Scheff, in anesthetizing the larynx by applications of chloroform, concentrated solutions of morphine with the addition of vinegar, alcohol, etc., likewise could not be substantiated. These applications produced a tolerance of the laryngeal mucous membrane to pain in only a small percentage of cases, and were not without danger, owing to the severe irritation of chloroform. In the use of morphine in such large doses, according to Harris, $\frac{3}{8}$ of a grain, the possibility of poisoning was always present. Schroetter in his early experience with this method had one death from morphine poisoning. Scheff also warns against the repeated painting of the larynx with chloroform and morphine. Tobold never had satisfactory results with the Tuerck method, and it may be said that in all cases where a satisfactory anesthesia of the larynx was obtained, the result was due to the systemic effect of the morphine. This method finally became obsolete following the extensive experiments of Zawerthal on dogs, and further confirmed by a large clinical experience.

The discovery by Alexander Wood, of Edinburgh, in 1853, of hypodermic injections by means of a hollow needle is an important historical fact in connection with our subject. His discovery was most important from the fact that drugs could be introduced directly into the circulation. It also gave us a new method of introducing different solutions of drugs into the tissues so as to come into more intimate contact with the nerve supply and there exert their chemical or physical action, something heretofore impossible. Wood started out with this in mind, using as his first injection solutions of morphine and tincture of opium; this he injected in the neighborhood of nerve trunks for the purpose of utilizing the local anesthetic properties of the drug for the relief of neuralgic pain. Morphine and opium were chosen for the purpose owing to the prevailing idea that sleep-producing drugs exerted their action at the site of injection. The injection of solutions of morphine to obtain local anesthesia in minor operations was used with partial success in the following year for the removal

of toe-nails, cauterization of wounds, and ulcers. In some cases results were no doubt due to the systemic effect of the morphine, as in a case of Jarotzky and Zulzer, where the strapping of a testicle with adhesive plaster was done without pain, likewise Walker was able to employ taxis in a case of strangulated hernia, and succeeded in reducing it without pain, following the injection of 1 grain (0.06) of morphine. Eulenburg injected $\frac{1}{8}$ grain of morphine in each side of the exit of the superior laryngeal nerve through the thyrohyoid membrane, and was enabled in this way to produce an absolute anesthesia of the larynx. Much later (1880) this same procedure was described by Rossbach, but control experiments by others were without results. Tobold, according to Eulenburg, found that sensation of the upper part of the larynx was diminished by these injections, but anesthesia sufficient for operation could not be produced. Chloroform injections were used for purposes of local anesthesia by C. H. Hunter, but were given up because the pains from the injections was far more severe than those from the operation. Pelikan and Koehler, the latter with great reserve, however, advocated the use of the glucoside saponin subcutaneously for the production of local anesthesia, but the severe pain due to this irritating drug, as observed by Eulenburg, Keppler, and Kappeler, prohibited its further use. The use of physiological solutions at proper temperature injected into the tissues for the purpose of dehydrating them and causing them to swell, belongs to more recent times and will be described later.

It will be seen from the preceding historical sketch how earnest were the constant efforts made during the past for a useful local anesthetic. After the introduction of general anesthesia these efforts were, if anything, carried on with greater zeal. In preanesthetic days surgical operations were always associated with pain in the minds of both physician and patient, but with the advent of anesthesia these conditions changed. Patients now demanded that operations be carried out without pain under general anesthesia, although the method was hazardous. On account of this danger the desire still prevailed to find a method of painless operating without the drawbacks of general anesthesia. The approach to our subject takes us back again to the history of ancient times where the means to the end had already been indicated. In every possible manner, both physiological and chemical, attempts were made to influence sensation in the nerve trunks or their endings for the production of local anesthesia by the use of cold, compression, and drugs of all kinds. Drugs were applied to the skin and mucous membranes, their absorption being aided by the electric current, or they were injected; yet the only method of use handed down to modern times was the application of cold. The efforts to discover an efficient chemical anesthetic, which was the punctum saliens, failed completely, and until the discovery of such drugs, local anesthesia was without tangible form. The new era, therefore, began in 1884 with the introduction of cocaine, which in its physiological reactions differed from all heretofore known substances. The history of local anesthesia was in the following years synonymous with cocaine anesthesia, and will be considered in another chapter.

CHAPTER II.

SENSATION AND PAIN—ANESTHESIA AND ANESTHETIC METHODS.

The ability of the living body to react to stimuli affecting its nervous elements so as to cause reflexes, perception, feeling, or conception is termed sensation. The senses of feeling, hearing, smelling, tasting and seeing, likewise pressure, temperature, and muscle senses, allow us to appreciate the condition of our surroundings as well as the nature of our own bodies, but what interests us particularly in this connection is the subject of pain. Pain is a sensation feared by man, the alleviation of which is being constantly attempted by the physician It, however, acts as a conservator of the species by giving evidence of illness in the human body. Pain from injury gives evidence of threatened danger from without which can still be avoided, or that damage to the body has already taken place requiring immediate attention to prevent more serious consequences. Pain acts as a monitor, warning us of improper ways of living which, if continued, will interfere with the general health. It precedes or accompanies the outbreak of disease and warns one that the body is sick and needs attention. Pain due to physical or mental overwork requires rest and recreation. The symptomatic pain of a diseased organ demands of the patient in a definite manner to protect that organ. Pain is the best assistant of the physician, and it is a strange duty that we physicians have to combat our own assistant. The sick follow its warnings obediently and demand definite advice for correct living from their medical advisers. Nature, by means of pain, compels even the most active to rest, the most wilful to observe proper living conditions for the diseased body. Pain is a severe but necessary law of Nature, but like all her laws is undeviating in its course, insensible in its regard to feeling, appearing, therefore, brutal and cruel. It appears not only as a beneficent monitor but also as a useless tormentor. In incurable disease, also in affections which though understood we are unable to influence, pain occurs and takes away unsparingly the pleasures of life without offering any bodily advantage in return (Goldscheider). Pain is often absent in the most dangerous diseases, thus giving the patient false assurance. It is present and must be relieved by the physician whenever the patient must undergo a life-saving operation. That it cannot be banished from the world is a certainty; in fact, we would not wish it otherwise. Pain is necessary not only for guarding us in the fight against the forces of disease, but also as a monitor of our ethical emotions, for in the recollection of pain, either physical or mental, lies in large part the cause of compassion and the helpful love of mankind (Goldscheider).

Pain sense like all the other senses is associated with the functioning of the cortex of the brain. According to Flechsig the pain-transmitting fibers end in the cortical sensory area, the latter corresponding in part to the cortical motor area. By interrupting fibers from the corona radiata, in the region between the anterior and posterior ends of the thalamus, complete anesthesia is produced on the opposite side of the body (Tuerck's hemianesthesia). Flechsig believes that the center for painful impressions is located in a different area of the sensory cortex than the sense of touch, probably in the forniculate gyrus. Painful sensations following irritation are probably conveyed to the brain through the peripheral sensory nerves of the brain and cord. In the cord it is generally believed that painful impressions are transmitted exclusively through the gray matter.

A suitable irritant (mechanical, chemical, thermic, or electrical) can produce pain equally as well when affecting the end organs as when affecting the nerve in its course. The former painful sensation appears to be much more severe than the latter. It has been demonstrated by the surgeon that the brain, at least on its convex surface, is absolutely insensitive to pain or pressure. No difference can be recognized between sensory impressions, since it is very improbable that direct irritation of certain definite parts of the brain can give rise to the sensation of light or hearing, etc. For the brain to become responsive, it seems necessary that the irritant be transformed in some way by the outer sense organs. Clinical experience seems to prove that neither the brain nor the cord has pain sense. Painful impressions produced upon the cerebral cortex are projected from the brain to various parts of the body, likewise irritation of a sensory nerve trunk produces its effect in the area of distribution of the nerve. If the trunk of the ulnar nerve is pricked at the elbow with a fine needle, sensation or paresthesia will be experienced in the fourth and fifth fingers; a second pain will now be experienced at the point of irritation, which irritation may be conceived as a sensation of pressure, temperature change, or pain. Since nerve fibers possess no local indicator for points in their continuity, it is to be assumed that this feeling of pain must be transmitted to the brain by the nervi nervorum (Goldscheider). The localization of painful impressions, as is well known, is very often uncertain and gives rise to various errors. Pain in a definite part of the body or in a certain organ can originate in this part or organ, or be due to the stimulation of its conducting nerves or of the brain itself. Although the brain is apparently insensitive to ordinary stimuli, there is no doubt that pain is often not peripheral but of central or cortical origin.

It is still undecided whether or not pain is a particular form of sense energy traveling along particular paths with special end-organs. The most generally accepted theory is that of Goldscheider, who claims that pain is produced by excessive irritation of the usual centripetal nerves of pressure and common sensation. Pain and pressure sensations are not different varieties, but due merely to a difference in degree of the irritant; with slight stimulation, the feeling of pressure or touch occurs, while when a certain degree of irritation is exceeded, then besides, or instead of

the special sensation, pain is felt. Frey opposes this theory and holds strongly to the existence of special nerves of pain, having their end-organs in the intra-epithelial cells of the skin. Both of the above theories are supported by actual observations and clear-cut reasoning, but to decide between them would be out of place at this time, except to say that in certain clinical cases of disease of the brain or cord associated with isolated paralysis of the senses of feeling or pain, it would be very difficult to explain these conditions if we did not believe in the existence of separate tracks and end-organs. The experiencing of excessive pain from irritation is called hyperalgesia; a diminution of pain sense is termed hypalgesia. Hyper- and hypalgesia are very often of central or physical origin. The expression and degree of pain varies greatly with the individual and is influenced by innumerable circumstances, such as character, breeding, the intelligence of the individual, his general conception of things, nationality, age, sex, and general physical condition.

The outward expression of pain is of course no guide as to its actual intensity, as pain is largely dependent upon the psychical condition of the patient. A sudden unexpected injury of the body is not found to be painful; a needle-prick is painful when expected. If the mind is otherwise occupied or in a state of excitement no pain is felt. Kant was able intentionally to concentrate his mind on certain themes, so as not to feel the pains of gout from which he was suffering. The thought of pain, or better, the fear of pain, as we are really not able to imagine severe pain, increases its intensity. Strong-minded, intelligent persons give less expression of pain than weaker or less intelligent ones; the latter will feel pain where others would not. The tolerance of pain varies with the epochs of time and the class of people. Those of the hard and cruel Middle Ages were less sensitive than those of the modern world of culture; even today the uncivilized races are less sensitive. We cannot compare the atrocities of the Middle Ages and those existing among certain tribes of the present day, or the castigation, self-mutilation, or self-offering of Christian and heathen fanatics with our conception of pain. We need have no sympathy with the actor who in public allows needles to be stuck into his body, as appreciation of pain is entirely lacking in him. Mucius Scaevola, who in a moment of intense excitement thrust his hand into the fire, did not suffer to the same extent as an individual compelled to do a certain act. People of the North seem to be less sensitive than those of the South; city-bred are more sensitive than the majority from the country, while old persons are more tolerant than those in the prime of life. The physician, and more particularly the surgeon, meets with these physical variations of sensation almost daily, and he must know beforehand what demands he can make on the patient to be operated upon without an anesthetic. Certain it is that the conduct of patients during painful procedures is often only a variation in the outward expression of pain; nevertheless we must assume that in certain individuals and some races the physiological pain sense is less highly developed than in others. In the newborn the pain sense is only slightly developed, it being very prob-

able that this sense is developed later in life and to a varying extent just as the other senses are developed. How and in what form hyperesthesia and hypesthesia occur in diseases of the brain and cord we will not discuss at this time.

Peripheral causes can produce an aggravation or lessening of pain. The pain sense of organs or tissues, when the latter are subject to disease, is often increased, seldom diminished. Acute inflammation and fluids confined under pressure give rise to spontaneous pain and often excessive hyperesthesia. The fact that an organ without feeling in health may, under pathological conditions, suddenly become painful is difficult if at all possible of explanation. The ability to receive and transmit painful impressions to the brain must be present in the healthy state if disease can increase it. It might also be mentioned that local disturbances of nutrition, such as chronic edema, can diminish the sensibility of a part; the cause is probably to be found in the fact that the physical and chemical composition of the edema fluid is different from the normal nutritive fluids so necessary for the correct functioning of nervous elements.

Of no small importance for local anesthesia is the distribution of pain sense in the different organs and tissues. It is certain that organs have parts of marked sensibility, areas of diminished sensation, and in places absence of feeling. To arrive at positive conclusions is not easy, as experiments would have to be conducted on living human beings. Then again we possess no means of measuring the intensity of pain. We are largely dependent for facts of this kind upon experience gained in operating upon the unanesthetized patient. In more recent times Bloch and Lennander have investigated this subject and collected what little was to be found in the old literature. The observations of Bloch are rather misleading and, therefore, objectionable because they were made among a people apparently very insensitive to pain and were carried out under the suggestive influence of the operator, and in many cases small doses of chloroform were given sufficient to bring about the so-called stage of analgesia. Some few observations on the sensibility of organs to pain are noted by Schleich and others who describe operations under local anesthesia.

The skin with its innumerable nerve endings can be said to be the most sensitive tissue in the body. In olden days when amputations and herniotomies were performed without general or local anesthesia, patients complained most when the skin was cut, while the balance of the operation was comparatively free from pain (Montfalcon). Bloch cites numerous proofs to support the fact that many operations are easily borne if the skin alone is rendered insensitive. Pain perception in the skin is not evenly divided over the surface of the body (the skin of the back, for instance, being much less sensitive than that of the finger tips), the extensor surfaces of limbs being in general less sensitive than the flexor surfaces. In disease, particularly the acute inflammations, the skin becomes extremely sensitive, so that the slightest touch, in fact every manipulation in the region of the inflamed area, is very painful.

The loose subcutaneous connective tissue obviously possesses very

little or no feeling, though numerous conducting nerves containing sensory fibers for the skin traverse this area. These nerves frequently lie near the bloodvessels and are contained in strong connective-tissue sheaths. The larger the nerve trunks the more deeply they are situated, usually in the region of the fascia. Pain of varying intensity, depending upon the location and the individual, is often produced by cutting, pressing, or pulling on the nerves in the subcutaneous tissue with hooks or other instruments, or in picking up and tying bloodvessels. The nerve distribution in muscle is practically the same as that in connective tissue. In operating upon unanesthetized patients one finds in the numerous connective-tissue septa of the muscle bundles many areas painful to mechanical irritation; these correspond to sensory nerve tracks. Sticking a needle in the muscle of a healthy person is in most situations free from pain, but if one of the sensory tracks is touched by the needle pain promptly occurs. Tendon tissue appears to be without feeling, as can be readily demonstrated during tendon suture; however, the connective tissue surrounding tendons, tendon sheaths, muscle fascia, and the associated layers of connective tissue possess a varying degree of pain sense due in all probability to nerve endings in these parts. Besides observations made during operations upon injured parts, one can readily demonstrate these facts upon his own body. Use for this purpose a very fine steel needle. This is passed through the skin into the underlying connective tissue in any part of the body, after first making the skin insensitive by the formation of a wheal in the manner to be described later, so that the skin sensation can be excluded. The needle can be moved in all directions parallel to the skin surface and, as a rule, no pain is felt. Only in certain places where the needle encounters nerve trunks will there be sensations of paresthesia or pain. The needle is now passed perpendicularly into the deeper parts and as soon as it comes in contact with the muscle fascia or the surrounding connective tissue pain is experienced, as a rule not excessive; in some few places there seems to be an absence of sensation. This pain is fairly well localized. Sensations other than pain, such as pressure or touch, are never produced in fascia; likewise sensations of paresthesias which are characteristic of the irritation of nerve trunks going to the skin never occur. Pain of a like character is felt when the needle-point touched the surface of tendons such as the tendo Achillis. The transfixing of this tendon is painless, yet when the needle emerges upon the opposite surface the pain is again felt. The sensation is always one of pain, and never any other. Tenotomy of the tendo Achillis with only anesthesia of the skin is for most persons a very painful operation, even though contrary to the experiments of Bloch.

Periosteum, according to Haller, Piory, and Bloch, possesses no pain sense, at least in the healthy state. This appears rather extraordinary considering the richness of its nerve supply. This assumption is certainly not correct, for if the periosteum of a healthy unbiased person is tested with the point of a needle in the manner before described, places will be found where it is extremely sensitive. The anterior surfaces of the tibia,

ribs, patella, and alveolar processes have scarcely any point which is not as sensitive as the skin itself. The pain is fairly well localized, and, according to Nyström, has a more diffuse heavier character than the skin pain. On the posterior surface of the tibia and the outer surfaces of the femur, radius, and fibula, experiments have demonstrated that painful areas are much less numerous, and that there are places between the painful areas where the needle produces no localized sensation. It appears that the pain was felt only after severe prodding with the needle so as to jar the entire bone. No other sensation than pain is produced by irritation of either periosteum or bone. In head injuries with exposure of periosteum, tests of this membrane or attempts at stripping same from the bone are, without exception, very painful. Sensitiveness of the periosteum of the jaw is a daily observation, the degree of sensitiveness as in all other parts being in large measure influenced by the place and the individual. In general, therefore, the periosteum must be considered a very sensitive structure even under normal conditions. Lennander's observations coincide with these findings.

In regard to the pain sense of bone or its marrow the following should be noted: Montfalcon says that patients undergoing amputations complain bitterly of pain on cutting the skin, less on cutting muscle, and not at all on sawing the bone. Piorry, on the contrary, claims that the medulla of bone in sawing, passing sounds, or on the injection of irritating fluids is extremely painful. Reid in describing amputations under local anesthesia claims that a short narcosis is necessary in sawing through the bone. Schleich also claims that the bone and medulla are sensitive. According to the observations of Bloch, in amputations and chisel operations the medulla has sensation, but no pain sense. The cases in proof of this assertion are not very strong evidence as they were carried out under light chloroform anesthesia. Bichat, quoted by Bloch, claims that pain sense is more marked in the central part of the diaphysis of long bones than toward the epiphysis. The medulla of short and flat bones is less sensitive.

A long bone from which the periosteum has been removed can be chiseled into without pain. Nyström demonstrated by experiments on himself that the cortical layer of the tibia was completely insensitive to a depth of several millimeters even when the opening made in the periosteum has a diameter of only a few millimeters. He concludes therefore that it is improbable that the bones in general receive pain nerves from the periosteum. The medulla of bone, according to Schleich is not free from pain sense, and he thought it necessary to anesthetize it. Piorry's observations that probing bone sinuses is often painful is undoubtedly correct. According to the author's recent observations made on large cavities in the tibia, the anterior wall of which had been destroyed by osteomyelitis, although the periosteum of the posterior surface of the bone was retained, painful sensations were only experienced in a few places in the bone, and not of severe degree. Such bone cavities can be curetted, and only when the periosteum at the margin of the cavity is touched does the patient complain of severe pain. Other sensations than pain are not

observed in such a bone; pressure and temperature senses are positively absent. Only the shaking of the entire bone or extremity is felt, which is probably due to the change of position. Nyström's investigations showed that the medulla of the tibia and femur contained pain nerves in some places, which on irritation produced a sensation of dull pain. Also in the spongiosa on certain places similar painful sensations are produced. In both the medulla of the long bones and in the spongiosa these sensitive places are found especially near the cortical layer.

Cartilage is insensitive (Bloch, Lennander), while perichondrium, when present, is rich in nerves and sensitive to pain.

Joint capsules, ligaments, and synovial membranes positively require to be anesthetized before operation. The sensitiveness of synovial membranes is very pronounced, even in uninflamed conditions, which is certainly to be expected in consideration of their ample nerve supply. The injection of irritating fluids into a joint is usually very painful; also in arthrotomy of the knee-joint the synovia was found very sensitive. Joint capsules and ligaments always contain nerve tracts which cause more or less pain on pulling or cutting. Haller considers ligaments and capsules insensitive; according to Bloch, no one tissue of a joint possesses marked pain sense. The example which Bloch gives among others to prove the truth of his assertion is as follows: Girl, aged twenty-nine years, suffering from a chronic ostitis of the external condyle of the femur. An Esmarch band was applied, ethyl chloride sprayed on the skin, after which an incision 6 cm. long was made without pain. The knee-joint was opened and its interior probed in all directions to determine its sensibility. The periosteum was separated from the external condyle and the diseased bone area was removed with chisel and curette. The operation lasted eleven minutes; the patient experienced no pain, which cannot be ascribed to the ligation of the extremity, owing to the short time required for the operation. A similar example of a painless operation may be noted: On July 7, 1899, a laboring man was operated upon for a pseudoarthrosis of the ulna. Except that he was slightly excited his nervous system was perfectly healthy. The skin incision was made after infiltration with cocaine, the bone was exposed, periosteum separated, the connective tissue between the bone ends was excised, the bone ends freshened and sutured with wire, and the wound closed with sutures. The patient felt no pain during the entire operation, lasting one hour and a half.

October 19, the operation was repeated without an anesthetic of any kind, as bony union had not taken place. The operation was again performed, without pain according to the statements of the patient. The question of anesthesia in cases of this kind can be readily explained, for whether the skin is deadened with ethyl chloride or not, the patient does not complain and does not feel the pain of operation. To generalize from such experiences, which, no doubt, all surgeons have had, is not possible, and to use such patients for studying sensation is of no value. It is scarcely worthy of consideration to believe that the tissues before mentioned, innervated by the cerebrospinal nerves, can develop a high grade of pain

sense in consequence of an acute inflammation or a central or physiological hyperesthesia, and under ordinary conditions be free from pain.

The mucous membranes of the mouth, nose, and pharynx are all more or less sensitive to pain in the healthy state; this can likewise be said of the mucous membrane lining the antrum of Highmore, the frontal sinuses, and tympanic cavity.

We encounter now for the first time a truly insensitive organ, namely, the mucosa of the stomach and intestinal tract. Absence of sensation, even in the most sensitive persons, begins in the esophagus, the swallowed morsel being lost to sensation as soon as it passes the pharynx. This lack of sensation extends to the rectum, painful sensation again appearing in this part and becoming most pronounced in the anal portion. The absolute lack of sensation of the mucous membrane of the colon to mechanical, chemical, and thermic irritation was observed by Steinhaeuser in 1831, and can be readily demonstrated on the anus preternaturalis when fixed to the anterior abdominal wall, or after excision of the rectum; on the sigmoid, fixed either to the anal or sacral region. These experiments were carried out, among others, by Block and Lennander; the author has also been able to demonstrate the insensitiveness of the sigmoid years after the excision of the rectum. The sensibility of the abdominal organs will be considered again later. The degree of pain sense in the larynx does not seem to be very pronounced, but it is difficult to determine, owing to the highly developed reflexes in this organ. Foreign bodies in the larynx, or a diseased condition, only cause severe pain when producing pressure on the perichondrium. The tracheal mucosa, according to Bloch and Lennander, is insensitive.

The urethral mucous membrane under normal conditions is very sensitive, though Bloch declares the cutting of the urethral orifice to be but slightly painful. This statement will be borne out by very few patients. Whether the pain following the stretching of the urethra occurs in the mucous membrane is questionable. The mucous membrane of the normal bladder is more or less sensitive; in fact, parts are found without sensation. Bloch reported on opening the bladder by sectio alta that the inflamed mucous membrane at the fundus was insensitive while that at the neck of the bladder was quite tender. Suprapubic cystotomy is frequently performed today under local anesthesia, and has demonstrated that the bladder mucosa is everywhere more or less sensitive and requires to be anesthetized. The mucous membrane of the introitus vaginæ is extremely sensitive, that of the vagina very much less so, notwithstanding Lennander's claim that the vagina is insensitive. The mucous membrane of the uterus is only slightly sensitive.

Another organ which gives absolutely no reaction to outside stimuli is the brain. As has already been stated, clinical experience with diseases of the brain does not sustain the assumption that this organ has any pain sense. Observations by surgeons have established the fact that at least the convexity of the hemispheres is insensitive. On two occasions this observation was made with patients who were perfectly conscious; the

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first was a patient in whom an abscess was opened in the motor area, because it was thought in this instance that the abscess was deeply located in the hemisphere on account of persistent temperature; the other observation was made during a secondary operation on a patient with a bone defect in the skull, when recurrence was expected following the removal two years before of a gliomatous brain cyst. In both cases the hemispheres were punctured in all directions, and in the first case the abscess was incised. The patients complained of neither pain nor other sensations. Block, Schleich, and Lennander have demonstrated the insensitiveness of the exposed brain. With the change of dressing following operations on the brain and in complicated fractures of the skull all surgeons have observed that the brain is insensitive. The dura mater, according to Piorry, quoting Berefield, Legat, Fontana, and Caldani, is sensitive to pain, while Chaussier, Richerand, and Portal (cited by Bloch) hold the dura to be absolutely insensitive. At the present time it has been found in operations on the convexity of the skull that the dura is absolutely insensitive, while operations toward the base are painful. These facts were demonstrated on two different occasions, the first time during an osteoplastic resection of the skull for the removal of a glioma in the motor area. Toward the convexity, the dura was insensitive as usual, while toward the base about the height of the malar bone the dura was painful. In the second case a dermoid of the occipital bone in the region of the occipital tuberosity had perforated both the external and internal table of the skull and was adherent to the dura. After anesthetizing the external nerves it was possible to dissect free the cyst and remove the overhanging parts of the external table without pain; cutting the dura, however, was very painful notwithstanding the absence of pain in all other parts.

Observations as to the results just mentioned have been proved in late years by numerous operations on the skull and brain carried out under local anesthesia. The dura of the posterior fossa, which according to former observations was considered insensitive, proved according to later observations in operations on the cerebellum sometimes more or less severely painful, although the skull as a result of local anesthesia was perfectly without sensation.

We have to thank Lennander for his interesting and important observations on the sensibility of the abdomen and the abdominal organs. The older statements in this regard are very conflicting. Haller claimed that the peritoneum and mucous membrane of the intestines were without sensation, while the submucosa possessed feeling. In animals the liver, spleen, and kidneys were found to be very slightly sensitive. Piorry claimed the serous membranes were insensitive, and cites the experience of Bichat as proof, the latter having seen dogs eat their own intestines which had been extruded through an abdominal wound. E. H. Weber held that prolapsed human intestines were insensitive to cold, pain and pressure. Since the introduction of cocaine many abdominal operations have been performed without general anesthesia, and surgeons have had ample opportunity to convince themselves of the insensitiveness of the stomach

and intestinal tracts, together with their peritoneal covering. The opinions of Flourens, Richet, and Bloch were that abdominal organs in an inflamed condition could become painful. Lennander refuted these statements in consequence of many individual observations, carried out partly under local anesthesia on organs brought outside of the body or sewed in the abdominal wall. He proved conclusively that the peritoneum of the anterior and posterior abdominal wall, pelvis, and diaphragm, the latter as far as it is supplied by the spinal nerves, were sensitive to pain whether in a normal or diseased condition. The visceral peritoneum of the stomach, intestines, omentum, gall-bladder, kidneys, and liver, even in the state of acute peritonitis or other diseased conditions, does not possess sensory nerves reacting to the usual mechanical and thermic irritation, for the production of pain, touch, warmth, and cold. These parts can, therefore, be crushed, cut or burned without producing any sensation. The pain elicited from the parietal peritoneum by the use of clamps, cutting, burning or pulling, is very pronounced even in health, and as a rule is much increased in inflamed conditions. The pain can be localized in so far as the patient knows whether the irritation is right or left or in the upper or lower parts of the abdomen. Lennander, experimenting on the mesentery, could not arrive at positive results; pulling on the mesentery produced pain, and he believed that operations on the mesentery were pain-free if pulling were avoided; nevertheless, he observed that clamping the mesentery of the appendix with an artery forceps produced severe pain.

That the observations of Lennander are correct, as far as they concern the walls of the stomach and intestines, has been proved by surgeons in hundreds of cases. No matter under what conditions the operation is performed, whether the patient's abdomen is opened under "ether narcosis" or the abdominal wall is made insensitive with cocaine or other anesthetics, whether the operation is carried out under general anesthesia or other sedatives, whether the intestines are operated upon after being out of the abdomen for a long or short period, or whether the stomach or intestines are sutured through a small incision of the abdomen and immediately opened, whether this particular part of the intestine is normal, inflamed, or otherwise altered, the stomach and intestinal walls are always found to be without sensation. At the same time the parietal peritoneum is extremely sensitive everywhere, unless made artificially anesthetic. Ritter is the only author who is supposed to have seen the small intestine in the human being sensitive to mechanical and thermic irritation.

Lennander has added much to our knowledge regarding the sensibility of the mesentery. In a communication from Bier, he states that according to his observations ligation of the mesentery is usually painful. Other observations made during an intestinal resection have also been described, in which every ligature caused severe pain. In many cases these painful reactions do not occur, particularly when the mesentery is ligated close to the intestinal wall. These observations seem to point to the conclusion that the sensibility of the mesentery varies, sometimes being close to the intestines, and at other times farther away from them. Wilms has verified these observations. It has also been demonstrated that the pinching of

the mesentery in an avascular area 6 cm. or more from the bowel is free from pain, while pinching the vessels 2 to 3 cm. from the bowel elicits pain. The close association of nerves and bloodvessels in the mesentery has been studied in animals and man by Ritter and Propping. It should also be noted that in strangulated hernia the mesentery is almost always without sensation, as the strangulation not only can but must produce loss of feeling. It is a fact well known to surgeons that the clamping of the mesentery in the deeper parts of the abdomen or the ligating of the lesser omentum, as a rule, causes severe pain to patients not under the influence of a general anesthetic. No one doubts today that the mesentery of the human being is possessed of a pronounced sensibility. The observations of Wilms and Hesse on the appendix and its mesentery are of much importance and coincide with the experience of others, viz., that the appendix has no pain sense but its mesentery is painful to manipulation. In ligating or clamping the mesentery of the appendix pain is complained of, not localized to this region but, as a rule, referred to the epigastrium. The intensity of this pain is quite variable, at times so slight as to be only determined by questioning the patient, at other times so severe as to require general anesthesia for its relief. This same sensation occurs from pulling on the appendix or cecum. The remainder of the mesentery reacts in a similar manner. The great omentum is usually, but not always, insensitive.

According to the experiments of Kast, Meltzer, Ritter, and Propping the walls of the stomach and intestines of dogs and rabbits are sensitive to pain, these results being alone denied by L. R. Moeller. Meltzer and Kast have made the observation that in animals poisoned with cocaine not only is the skin, cornea, and parietal peritoneum insensitive, but the sensation of the stomach and intestinal tract is also lost. It has been claimed by these authors that the diminished sensibility and absence of pain sense in the intestines of persons injected with cocaine for purposes of local anesthesia is of a similar nature, but Wilms, Propping, and Nyström have taken exception to this theory, as disturbances of sensation of this sort are brought about only by toxic doses of cocaine. This appears likewise in paralyses which are of central and not, as Ritter claims, of peripheral origin. Small non-toxic doses of cocaine (0.08 to 0.01 per os [Mossol]) do not cause diminished sensibility, but rather increase it. There is, therefore, not the slightest reason for doubting observations made on persons operated upon under local anesthesia, as they coincide with those made on patients operated upon without cocaine or similar drugs (Haim, Mitchell, Wilms, and Propping). Sensations during operation caused by pulling, clamping, or ligating the mesentery differ from other sensations, inasmuch as they are not localized and are apparently of a different character. Some patients do not speak of them as being painful but complain more of uneasiness; this latter feeling can become so severe as to be unbearable to the patient; others complain of colic-like pain. It might be suggested that we alter our terminology and call these expressions of feeling abdominal sensations.

In view of the marked variability of painful sensations in races and

individuals and the more pronounced character of abdominal sensations in certain animals, it is not suprising that a sensory zone of the mesentery is occasionally found reaching the intestine in man. It is only surprising that this observation was made by a single experimenter—Ritter.

Lennander's investigations culminated in the conclusion that the cerebrospinal nerves alone can receive and transmit painful impressions. The experimental investigations of Fröhlich and Meyer, the disappearance of abdominal sensation in spinal anesthesia and in paravertebral conduction anesthesia (Kappis), and, finally, observations in injuries to the spinal cord (Kocher) indicate that sensations are transmitted to the brain by way of the spinal cord and not by way of the vagus. On the other hand, the sympathetic nervous system plays an important role in the sensory innervation of the abdominal organs, for its sensory nerve fibers are transmitted partly directly and partly by way of the splanchnic nerves through the rami communicantes to the posterior roots of the spinal nerves. For particulars see Chapter XIII.

The author has often opened the gall-bladder under local anesthesia and can verify the findings of Lennander, namely, that the fundus is absolutely insensitive to pressure, clamping, or cutting, while pulling on the gall-bladder or sounding the gall ducts is painful; this latter can be demonstrated in all fistulæ of the gall-bladder. According to Ritter the ligation of the cystic artery and tying off of the gall-bladder are painful.

That the liver is without pain sense has long been known to surgeons. The opening of an ecchinococcus cyst of the liver, sutured to the abdominal wall, requires no more anesthetic than the opening of a loop of intestine fixed in like manner. In the opening of a liver abscess in two stages the convex surface of the right lobe, as well as the liver parenchyma, was found absolutely insensitive to pain and movement.

Lennander found the kidney, exposed by operation, to be insensitive to operative procedures as well as to heat and cold. It might be added that the kidney was freed of its fatty capsule. Bloch believes that the kidney has very little sensation, while Schleich contends that the kidney parenchyma is practically free from pain sense.

In regard to the uterus, Lennander found the surface of the fundus insensitive to the thermocautery, likewise the ovary and tube. He cited a communication from Viet in which the latter had repeatedly performed Caesarean section without anesthesia, of course not tying off the uterus or removing it from the abdomen. Reclus and Schleich state that in extirpation of ovarian tumors anesthesia of the pedicle is necessary. The portio vaginalis is not sensitive to pain, but the pulling down of the uterus during operation is painful. The peritoneum of the fundus of the bladder was found by Lennander to be insensitive.

Investigations regarding sensation in the testicle and epididymis are so incomplete that there is very little to be said at this time. This much is certain, that in operations on the testicle, complete anesthesia of the organ and its coverings is necessary.

The parietal pleura acts just as the parietal peritoneum, and is very sensitive to pain. This can be noted in every exploratory puncture. At

the moment of puncturing the pleura the patient complains of pain. This is equally true in thoracotomy if the anesthesia has been incomplete. This observation has also been verified by Lennander. The pulmonary pleura is insensitive. Garré, in describing the technic of lung operations, says: "In operating in two stages, pneumotomy can be performed in the second stage without general or local anesthesia; the lung tissue is almost insensitive." It is generally recognized that pleurisy is painful, while central pneumonia and chronic inflammation of the lungs unaccompanied by pleurisy is painless. Lennander has also positively determined that the thyroid gland is absolutely insensitive to mechanical, chemical, or thermic stimuli.

The sense of pain, as we see, is a property of the tissues widely distributed throughout the body. It is often present where the other senses or ordinary sensation is absent. Under the circumstances it is very probable that pain sense has special nerves with specific end organs for its transmission. From a practical point of view local anesthesia will only have a future and be able to compete with general anesthesia if all the tissues in the operative field having, or which may have, cerebrospinal nerves can be made insensitive. The only tissues not requiring anesthesia are those of the brain, abdominal organs, and lungs.

Anesthesia can be produced artificially by a break in the centripetal conducting sensory nerves, by a paralysis of function in the central end-organ in the brain, or by a paralysis of the peripheral end-organs in the tissues. If paralysis affects the function of the centers in the brain, we speak of a central anesthesia; this extends over the entire body and is usually associated with a disturbance of consciousness. The latter is intentionally attempted in general anesthesia for surgical purposes, very seldom in hypnosis.

Paralysis of the peripheral sensory nerve organs brings about a condition which in the terminology of the physiologist is called peripheral or terminal anesthesia. It is exactly confined to those tissues in which the function of the end organ is inhibited. If the conductivity of a sensory nerve is interrupted at any point between the brain and periphery, all the tissues supplied by this nerve alone will become anesthetic. This is termed conduction anesthesia.

Terminal and conduction anesthesia when used in eliminating pain in surgery are classed together under the terms local anesthesia or local analgesia.

The remedies at our disposal for the production of local anesthesia are partly physiological, and partly chemical in their action. Severe pressure on a nerve trunk renders it incapable of conduction. Severe or long-continued cooling, causing either a swelling or owing to the loss of water a shrinking of nerve elements, will cause a temporary loss of function. This same thing occurs when certain drugs, local anesthetics, are brought in contact with nervous elements. The object of the following chapter will be to give the history so far as not already mentioned and, furthermore, to thoroughly present the theory and practice of the various methods of producing local anesthesia.

CHAPTER III.

THE PAIN-RELIEVING ACTION OF NERVE COMPRESSION AND ANEMIA.

Mechanical pressure on a nerve trunk can cause a break in conduction, with consequent motor and sensory paralysis in the tissues supplied by it (conduction anesthesia). Daily observations in the living, such as the going to sleep of a limb, radial paralysis from pressure on the nerve trunk, experience gained in ligating a limb during amputations for purposes of checking hemorrhage, caused the physicians of former times to utilize this measure for purposes of local anesthesia. We have already followed this history up to the time Esmarch used the elastic tube or bandage for the purpose of rendering an extremity bloodness or for hemostasis, at which time it became an essential part of surgical technic. Many investigators at this time studied the physiological action of the anemia in limbs thus ligated, and the majority believed that both sensation and motion were affected. The actual results of these experiments in animals, and in healthy or diseased persons, seem to the majority of observers (Nicaise, Verneuil, Billroth, Fischer, Bruns, Chauvel, Riedinger, Kappeler, Karewski) to produce various forms of paresthesias in the ligated limb but little or no diminution to sensations of pain. Some few experimenters (Neuber, Iverson, Le Fort, Stockes), after ligating an arm or leg, found a fairly extensive anesthesia following, beginning in the fingers or toes and gradually extending to a greater or less degree over the entire extremity. Inasmuch as they all rendered the limb on which they were experimenting bloodless, to the point of interrupting the blood supply, it seems that the prevailing opinion as to the anemia of the tissues causing disturbance of sensation was not very probable. The old surgeons Juvet, Thedon, Liégard (see Chapter I) were never of any other opinion than that the pressure on the nerve trunks caused by ligating a limb produced conduction anesthesia in the peripheral parts. If attempts are made to control these experiments in such a way as not only to interrupt the blood supply but also to exercise a certain measured pressure on the nerve trunks, the following will be noted: Peripheral ligation anesthesia, as already noted by Krieshaber, Verneuil, etc., only occurs when the pressure of the constricting rubber tube far surpasses the pressure necessary to interrupt the blood supply. Very strong ligation is necessary in order to produce a diminution of sensation in a reasonable length of time, and then this is usually confined to a hand or foot. The intensity and extent of ligation anesthesia will be in direct proportion to the degree of pressure on the nerve trunks. The more widely distributed the peripheral sensory dis-

turbance, the greater the subjective pain at the point of ligation, the pain being often unbearable. The degree of pressure on a nerve is not only dependent upon the tightness of the ligature but also on the condition of the limb, the nature of the ligature, and the place of ligation. In the upper arm of a thin woman or child a carefully placed rubber band readily interrupts the blood-stream without causing peripheral sensory disturbance or subjective pain of any consequence. In muscular limbs this is not sufficient, and strong pressure is necessary for the interruption of the blood stream which at the same time interferes with nerve conduction. A wide rubber band naturally causes less pressure than a narrow one placed on a circumscribed area. A rubber tube wrapped tightly about a thin upper arm rapidly produces muscular and sensory paralysis, and, as is well known, the motor paralysis may be persistent. Motor and sensory paralysis occurs quickly in the area supplied by the radial nerve if a rubber tube is wrapped about the upper arm where the nerve trunk lies to the outer side and unprotected by muscle. For the reasons just mentioned the degree of pressure on the nerve trunks is difficult to estimate and easily explains the difference in the observations of the before-mentioned authorities.

A more suitable part for experimentation than the larger sections of the limbs are the fingers about whose base it is easy to regulate the degree of constriction under nearly constant experimental conditions, where firm constriction can be borne much longer without annoyance and where light pressure is sufficient to interrupt the circulation.

A number of rubber rings of different sizes and strengths are cut out which can be stripped on the fingers as far as the base. It is easy to determine by observing the color of the finger the rings which will produce the least degree of pressure sufficient to interrupt the circulation and those which will produce a medium and a greater degree of pressure, the greatest degree of pressure being produced by wrapping the base of the finger with a thin rubber band.

The results of these experiments can be explained in a few words. Bands of weak and medium strength are left in place two hours. With weak bands besides paresthesia and numbness, only a diminution of the sense of touch in the phalanx is noted. With medium bands loss of the same sense of touch is present, which beginning in the end phalanx gradually extends to the middle phalanx. The feeling of a needle-prick is probably increased after two hours; at any rate it is not diminished. Bands exerting strong pressure after half to one hour, besides the previously mentioned sensations, cause a distinct diminution of the sense of pain in the terminal phalanx which occasionally extends to the middle phalanx. Severe sensory disturbance is present during the time of ligation. On releasing the ligature, sharp, shooting pains of short duration occur in the finger. The disturbance of sensation always begins in the finger tips and extends toward their base, and the extent and intensity of this anesthesia is in direct proportion to the pressure, while the anemia of the tissues remains the same.

According to more recent investigations by Boeri and Silvester, pain sense of all the senses is the most resistant to pressure on the nerve trunks and disappears last. The first senses to disappear are those of touch and pressure, temperature sense occupying an intermediate position.

The author observed complete anesthesia of the finger but once sufficient for operative work. In this case the base of the middle finger was bound very tight with several turns of a very thin rubber band. In about fifteen minutes the finger was perfectly insensitive, and remained so after the removal of the band, and not until several months later did normal sensation gradually return. There were no disturbances of circulation at the site of ligation, the condition being due to a pure nerve lesion, a nerve crushing, as it were, with its usual consequences. After tight ligation of an arm or leg a persistent motor paralysis is more likely to result than a sensory paralysis. According to the experiments of Luederitz the motor nerves are more easily paralyzed and injured by pressure of a band than the sensory nerves; at the same time the sensory nerves recover sooner than motor nerves from pressure paralysis. These observations coincide exactly with clinical experience (anesthesia paralysis and compression myelitis).

We must conclude from these observations and experiments that the surgeons of old were perfectly right in attributing ligation anesthesia to pressure on the nerves. The anemia accompanying ligation, with its consequent disturbance of nutrition, is only of secondary importance, as a diminution or loss of sensation from this cause occurs quite late, as can be observed in tightly ligating a limb. A finger rendered anemic requires considerable time before a benumbed or painless condition ensues.

The reaction of nerve tissue to diminished or interrupted circulation is not uniform. The brain, medulla and spinal cord of warm-blooded animals is very sensitive to fluctuations of blood-pressure, while the peripheral nerve trunks, on the contrary, are independent of the oxygen supply to a great extent (Ranke and Ewald) and retain the power of transmission hours after the cessation of the blood supply (Schiffer). The end organs of sensory and motor nerves, exclusive of the retina, occupy a middle position between these extremes. Schiffer's experiments on warm-blooded animals demonstrated that it requires about one hour after the cutting off of the blood supply for loss of function to occur. In apparent contradiction to this is the so-called Stenson experiment (the high ligation of the abdominal aorta) of the physiologists, in which an immediate sensory and motor paralysis occurs in the lower extremities. Schiffer and Weil have shown that this sudden paralysis was due to the simultaneous complete anemia of the lower segment of the cord, and did not occur if the aorta was ligated lower down just above the point of its division, thus limiting the ischemia to the lower extremities. It was possible for Ehrlich and Brieger, in carrying out the Stenson experiment on rabbits, in those that lived long enough, to demonstrate that the largest part of a cross-section of the gray matter of the cord in its lower segment was destroyed as well as the more important motor areas in the white substance.

Singer and Spronck later studied in histological detail the cause and course of this anemia-necrosis.

This question will probably require further investigation, consequent upon the recent animal experiments of Katzenstein and the cases of Schlesinger, in which the latter saw ischemic sensory paralysis of the lower extremities occur a few minutes after the sudden blocking of their blood-vessels by embolism. The work of Schiff again disproves these observations; however, no matter what the outcome of this controversy may be, the fact remains that ligation anesthesia is due to pressure on the nerve trunks.

Ligation anesthesia is used just as seldom today in operations on the lower extremities as in former centuries. Esmarch, in his description of artificial anemias, says that he uses this procedure in all small surgical operations on fingers and toes, such as incision for felons, removal of ingrown nails, exarticulation of phalanges, etc. Stockes and Le Fort describe major operations, as the extirpation of a carcinoma from the back of the hand, resection of the elbow-joint, and amputation of the leg, performed in this way without pain. Again, in recent times Kofmann has advocated ligation for the production of anesthesia of the extremities, but this in all probability will not restore this measure to use again. The effect is too uncertain and the evil consequences too great. The necessary pressure on the nerve trunks must be so severe and the pressure dosage so uncertain that the danger of gangrene, permanent motor and sensory paralyses are avoided with difficulty. Kofmann experienced his first serious consequence of this method on himself. It should once again be emphasized that long-continued ligation of an extremity is extremely painful even for those not necessarily sensitive. For these reasons compression anesthesia was given up, even in those times when better and more certain methods of general anesthesia were unknown.

CHAPTER IV.

ANESTHESIA BY MEANS OF COLD.

Of much practical importance is the paralysis of nerve function by means of low temperatures. Although long known (see Chapter I), Arnott (1848) was the first to use this method in surgery to any extent. For the rapid chilling of the tissues he used muslin bags and pigs' bladders filled with a mixture of ice and salt laid upon the skin in the field of operation. He made the following observations: Anesthesia of the tissues produced by cooling was confined only to the outer sensitive parts, and inasmuch as the most painful part of many operations was located in these tissues, the application of cold was sufficient even if the patient experienced some pain, and was to be preferred to chloroform and ether, which caused loss of consciousness. The application of cold in this form is free from injury and danger to the tissues. According to Velpeau, Arnott's method of chilling the skin suffices for all superficial operations. Num, Herzog, Illig, Wittmeyer, and others heartily recommend this measure, and later, in 1876, Galeczowski used this method in lid operations. Ice and salt mixtures were soon discarded for the simpler method of using rapidly evaporating fluids.

Demarquay, Guérard, Richet, and others used sulphuric ether by dropping it on the skin in the field of operation and later constructed a blower for causing the ether to evaporate on the surface to which it was applied, and by this means found that the skin could be rendered insensitive. Ricket's experience (1854) showed that much progress had been made, for until this time local anesthesia never gave uniformly good results. The first real impetus to the use of cold as an anesthetic came when Richardson, in 1866, devised the atomizer, suggested to him by Giraldés, for the purpose of using ether and chloroform in a finely divided spray on the skin. Richardson's ether spray (Fig. 1) consisted of a finely-pointed metal tube through which a strong stream of air could be blown by means of a double rubber bulb; this mixed with the ether sucked through another metal tube from a glass container. By this means ether was finely subdivided and in condition to be rapidly evaporated, producing intense cold. For the extraction of teeth a fork-shaped end-piece with two openings was used. Under the influence of the ether spray the temperature rapidly dropped to —15° or —20° C., sufficient to quickly turn a test-tube of water into ice.

If the ether spray is used at a distance of about 5 cm. from the skin the latter becomes reddened, and in a few minutes white, hard, and insensitive; in fact, the skin is frozen. Sometimes the white and hard appear-

ance of the skin does not occur, yet the parts are insensitive; but these parts are irritated mechanically by rubbing the back of a scalpel over the surface, or by pricking it with the point of the knife the tissues change their color and consistency immediately and present the usual frozen appearance. All grades of ether can be used for this purpose. The best to obtain sufficient heat dissipation is pure water-free sulphuric ether having a specific gravity of 0.720 and a boiling-point of 34.5° C.; this is the so-called anesthetic ether of commerce. Sensitive tissues, as the skin of the scrotum, must be protected from the direct ether spray by coating the parts with vaseline or glycerin, or by interposing a metal plate (Prosoroff) between spray and skin. To prevent the unevaporated ether running over the skin, for instance in the region of the eyes, Lesser constructed metal boxes to fit various parts of the body. These boxes were filled three-quarters full of ether and by blowing a stream of air rapidly

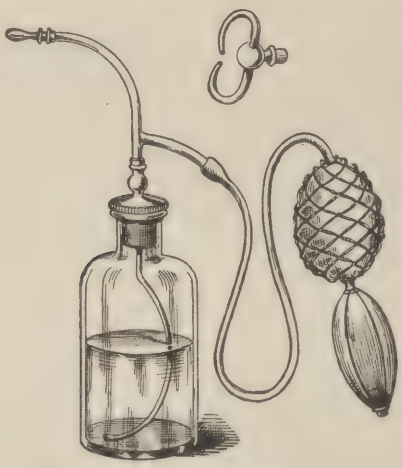

Fig. 1.—Richardson's ether spray.

through them, evaporation quickly occurred; the box was then pressed against the skin until frozen. Braatz constructed an apparatus along these same lines, which was used particularly for making very small areas of skin or mucous membrane insensitive for the purpose of injecting anesthetic fluids. These contrivances were unnecessary and never came into general use. The action of ether on the tissues is more intense, lasting and acting better on the deeper lying parts if the extremity is first ligated to prevent the access of fresh warm blood (Girard, 1874). The freezing of the tissues occurs very quickly by this method, and the thawing and return of sensation is very slow. Instead of ether, various other hydrocarbons can be used in the Richardson apparatus, only the more important of which can be mentioned here. Ethyl bromide (boiling-point +38°, Terrilon, Monad, Perrier, and Berger), carbon disulphide (boiling-point +48°, Simonin, Delcominette, Claude Bernard), petroleum ether (boiling-

point +38°, Bigelow, Warren), chloroform (boiling-point +61°), ethylene chloride (liquor Hollandicus, boiling-point +38°), amylene (boiling-point +35°), Robbins' anesthetic ether (a mixture of methyl alcohol and chloroform). The local anesthetic property of all these preparations is in inverse proportion to their boiling-point (Rosenthal, Bumm), the action being brought about by dissipation of heat due to rapid evaporation. Anesthesia must not be attributed to chemical or narcotic action on the sensory nerves at the point of application, as was supposed to be the case by early investigators. The only agent of those mentioned having advantages over ether is ethyl bromide, as it is not inflammable.

The experimental work of Gruetzner, Gendre, Heinzmann, and Fratscher takes up the physiological effect of cold on the nerve substance in animals.

Slightly cooled nerves retain their property of reacting to stimulation for considerable time; cooling to +5° C. inhibits the stimulation of all nerve fibers, cooling to the point of ice formation intercepts nerve function, the nerve, however, regaining its property of reacting to irritation on thawing. Sudden intense cold acts as a stimulus; slow cooling even to —4° to —6° does not stimulate. It is undoubtedly the cooling alone which brings about the molecular change and injury to nerves, which require a normal temperature for normal action. The effect of prolonged low temperature on the human skin is first to cause a contraction of the smooth muscle fibers of the skin and vessels. This is followed later by paralysis in them; the skin seems, therefore, at first pale, later livid. The circulation in the vessels of the skin is finally stopped, and partly from this, and partly from the direct action of the cold on living protoplasm, all functions are more or less rapidly destroyed, the tissues become insensitive, necrotic, or gangrenous, or serious disorders of circulation remain. These changes have been observed with temperatures above 0° C., but require a much longer time for action. The various senses of the skin do not react uniformly to cold. According to Boeri and Silvestro the sense of pressure remains intact a long time in the presence of cold; the sense of touch is less resistant than the temperature sense. The sense of pain is lost more quickly and completely than any of the other senses.

For the practical application of cold in local anesthesia very low temperatures are necessary for the rapid cooling of the tissues to the freezing-point (—0.55° to —0.56°). The length of time necessary to freeze the tissues depends not only on the rapidity of heat dissipation, but also upon the nature of the tissues, that is, the amount of blood in them, the rapidity of the blood-current, etc.; hyperemic tissues being cooled much more slowly than anemic ones. Sensory nerves lose their function as soon as the tissues are cooled below the freezing-point. There is a paralysis of the sensory nerve organs that is a terminal anesthesia to the extent to which the tissue is frozen. In rapidly cooling the tissues, anesthesia is preceded by pain; with the thawing of the tissues sensation rapidly returns, provided there has not been permanent damage to the parts in consequence of severe freezing long continued. In this case the insensitive area is

converted into one of marked hyperesthesia. All of these manifestations are to be considered as the immediate result solely of the freezing of the tissues. As previously described in connection with the ether spray, namely, that the already reddened skin with continued cooling suddenly becomes bloodless and white, and that this can readily be brought about if the reddened area is scratched with an instrument, is explained in a very weak and unsatisfactory way by Letamendi. He believes that anesthesia is brought about by a severe cramp of the vasomotor nerves. For this to occur the dilated capillaries must undergo contraction. This is rarely brought about by the ether spray, while a slight emptying of the hyperemic vessels, or a slight increase in tension of the vasomotor nerves which is produced by a superficial irritation, rapidly brings about the vessel cramp. Regarding this theory it is sufficient to say that a sudden contraction of the bloodvessels, with its consequent anemia, never immediately interrupts sensory impulses; moreover, loss of sensation often precedes the white appearance of the skin. The sudden hardening and white appearance of the skin can be more readily explained on a physical basis, these changes being due to the formation of ice in the tissues. The delay or non-appearance of this condition, as well as its sudden occurrence following mechanical irritation in tissues cooled below the freezing-point, is due to delay in crystallization. In determining the freezing-point of liquids, we find that albuminous fluids, such as blood, require cooling far below that of pure water before ice formation begins.

With the use of the newer agents for producing anesthesia by means of cold, the Richardson spray has been almost entirely superseded by sprays of more rapid action, these freezing the tissues very quickly without any other aid. The chemicals which are now being used have a much lower boiling-point than ether, producing intense cold on evaporation; for this purpose, ethyl chloride, methyl chloride, and liquid carbonic acid gas are the most useful. These agents at the ordinary room temperature and under normal atmospheric pressure change to gas, so that they must be kept in containers under pressure.

Ethyl chloride (Kelene), C_2H_5Cl, is a colorless gas which at a temperature of $+11°$ C. is converted into a colorless liquid. Pure or mixed with sulphuric ether, Rottenstein in 1867 used it for purposes of local anesthesia, but it was only through the efforts of Redard, Baudouin, Ehrmann, Gans, and von Hacker that ethyl chloride became extensively used in surgery and dentistry. This agent was formerly made only in France and Switzerland, but is now produced in almost all countries, the quality being equal to the imported article and the price more reasonable. It is handled in the shops in the form of either metal containers or glass tubes, sealed or having metallic closing devices, the quantity varying from 10 to 100 cc. The most convenient package is the glass tube with a metallic screw top, having a capillary opening at one end or at right angles to the tube. The tubes are opened by unscrewing the cap or breaking the capillary tube. Another convenient container is on the market with an opening closed by a cap operated by finger pressure. These tubes can be returned to the

factory to be refilled. The warmth of the hand is sufficient for vaporizing the fluid which is forced out in a strong stream. The evaporation of ethyl

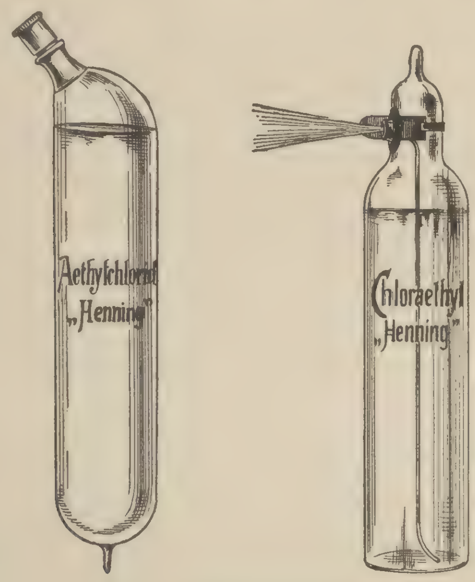

FIG. 2.—Ethyl chloride tubes.

chloride produces a temperature of —35° C. and causes immediate freezing of the skin if held between 30 to 40 cm. from the surface. The freezing

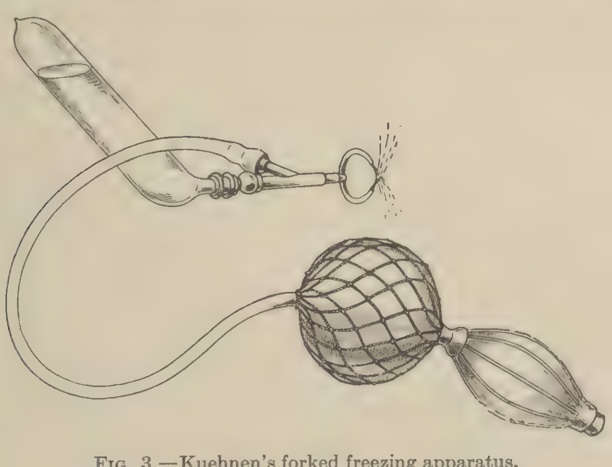

FIG. 3.—Kuehnen's forked freezing apparatus.

is much facilitated by blowing on the liquid, thus aiding its evaporation. The so-called Kuehnen's fork spray (Fig. 3) is a valuable addition to the

ethyl chloride container for use in the extraction of teeth. This apparatus permits a constant stream of air to pass through the two openings through which ethyl chloride is passing, thus causing rapid evaporation, both sides of the tooth and gums being sprayed at the same time. For the method of application see Chapter XI.

Methyl chloride, CH_3Cl, under high pressure, is a clear liquid which boils at a temperature of $-23°$ C., for which reason it must be kept in metal cylinders. Lallier and Debove were the first to recommend this agent for local anesthesia. They allowed the stream of liquid to play upon the skin direct from the container, producing a temperature of $-55°$. This very low temperature could easily cause injury to the skin, as blistering, or even gangrene.

It seems safer and more practical, if one desires to apply this liquid, to use Bailly's indirect method. Tampons varying in size and form, consisting of cotton on the inside, the exterior of floss silk, and a single layer of silk gauze, are saturated in methyl chloride either by playing a stream of methyl chloride upon them or dipping them into the fluid, which may be kept nearly three hours in the thermoisolator constructed by Bailly. This apparatus consists of a glass tube, 15 cm. in length, placed vertically in a glass vessel resting upon a wooden support. The circular space between the upper edge of the tube and the outer glass vessel is hermetically sealed and the air between the tube and the surrounding glass vessel is exhausted. The whole apparatus is then isolated by a poor conductor of heat and the inner tube containing the methyl chloride closed with a cork containing a capillary glass tube in order to allow the escape of the volatilized fluid. The tampons are held in wooden or vulcanite tongs or forceps, and are saturated in the above fashion in the methyl chloride. Bailly calls the forceps for holding such a tampon "Stype" and the procedure "Stypage." The tampons are placed upon the skin at the point to be anesthetized and left there until the tissues are frozen, which usually occurs after a few seconds. By means of a camel's-hair brush soaked in methyl chloride the anesthesia can be confined to minute areas. This agent even when used in this indirect manner can, by careless manipulation, cause destruction of tissue (Feibes).

Under the trade names of Anästol, Anästyl, Metäthyl, Koryl, various mixtures of ethyl chloride with methyl chloride find their way into the market. They act more quickly but less thoroughly than ethyl chloride, and are used in the same manner.

Still greater care is necessary in using the fluid and solidified carbon dioxide recommended by Wiesendenger and Kuemmell for anesthesia. The direct application of a stream of this fluid, boiling at $-78°$ C., upon the skin is naturally prohibited. According to Wiesendenger the fluid CO_2 is passed into a metal tube or the container is filled with closely packed CO_2 snow. Anesthesia is produced by contact of the metal tube with the skin. Caution is also necessary with this method.

Of all the cold-producing agents referred to, pure ethyl chloride next to the ether spray is highly recommended and has rapidly come into

extensive use. The small glass containers used in dispensing ethyl chloride are very convenient for use, and the cost small; 100 cc costing about $2.00. Inducing anesthesia by freezing the skin or mucous membrane, even in vascular tissues, is produced in the fraction of a minute, injury to the tissue being easily avoided, provided proper precaution is used. The spray of ethyl chloride should be discontinued as soon as the superficial layers of the tissues are frozen, as continued freezing for the purpose of obtaining deeper anesthesia will almost always result in permanent injury to the tissues. It is inadvisable and also unnecessary to combine artificial anemia with the ethyl chloride spray. No matter how advisable an artificial anemia may be, in the application of an ether spray so much the less is this the case when using ethyl chloride, as the cold produced by the latter is so intense that a dermatitis, vesiculation or superficial gangrene may occur in a short time on extremities made anemic by ligation. Covering the skin with vaseline or glycerin, as recommended by many, does not noticeably reduce the effect of the cold. It serves merely to protect the skin from chemical irritation of the anesthetic agent, as when using sulphuric ether. Ethyl chloride does not irritate the skin.

There is no reason to use fluids having a lower boiling-point than that of ethyl chloride, the supposed advantage of a more rapid anesthesia being more than counterbalanced by the fact that the artificial cooling must be interrupted so quickly that the anesthetizing effect is always more superficial. The Richardson spray should not be entirely forgotten, although it takes a few minutes more to freeze the skin and make it insensitive; but there is no doubt, and it is also quite natural, that by the slower cooling of the tissues it is possible to blunt the sensation of the deeper parts without the danger of injury to the skin. The preceding nerve irritation is also lessened the slower the freezing is induced.

The inflammability of many hydrocarbons and their vapors requires great caution. In the presence of an open flame or a glowing cautery the ether spray should not be used. Fluid methyl chloride or ethyl chloride, though combustible, are not explosive and their vapors will not ignite in an open flame. Consequently there is no danger following the use of ethyl chloride spray with the thermocautery. Ethyl bromide and carbon dioxide are not at all inflammable. Ethyl chloride having pure basic cocaine in solution has recently come into use in connection with the latter drug (Bardet), but inasmuch as ethyl chloride serves merely as a solvent we will discuss this mode of application of cocaine in another place.

Anesthetizing by means of cold has the advantage of simplicity of application. By the addition of tubes of ethyl chloride to the physician's armamentarium he can without much previous technical training induce anesthesia by cold. Against these advantages there are disadvantages; since it is by no means an ideal method of producing local anesthesia. The danger of injuring the tissue by freezing may with care be prevented, at least it very seldom occurs in vascular portions of the body. The usefulness of this method is curtailed by the fact that the anesthesia does

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not penetrate very deeply and that the healthy and diseased tissues are not easily differentiated after being frozen. Another disadvantage is that the freezing as well as the thawing of the tissues is painful, especially in inflamed and hypersensitive parts. For this reason the production of local anesthesia by means of cold has from its introduction until the present day been used solely for short and superficial operations. The attempt to use it in major surgery has been limited to isolated cases. Dolbeau made a resection of the scapula with satisfactory results by the repeated application of the ether spray to the cut surfaces. This method must be considered most impractical owing to the imperfect anesthesia in most cases and hemorrhage not being controlled by the ether spray. In large part the cold itself is a disadvantage, because it prevents a careful dissection of the deeper layers, coats the instruments with ice, and robs the fingers of the sense of touch (Kappeler).

Spencer Wells attempted an ovariotomy under the ether spray. The abdominal incision was free from pain, but loosening the adhesions necessitated chloroform anesthesia. Richardson and Greenhalgh completed a Caesarean section almost painlessly by aid of the ether spray. There is no doubt that of all the major operative work the abdomen lends itself most readily to this method of anesthesia. The reason for this is not because of the perfection of the method, but owing to the fact that many abdominal operations can be performed painlessly. If the skin and abdominal wall are made insensitive, the subsequent manipulations often give little discomfort. The general introduction of this procedure, recently suggested by Bloch, should be accepted with the same misgivings. Bloch believes that the anesthetizing of the skin by means of ethyl chloride suffices for many major operations without causing the patient much pain. He reports 503 such operations, including many herniotomies, tracheotomies, thoracotomies, colostomies, etc. It is undoubtedly true that in many major surgical operations, especially abdominal section, the skin incision is the most painful part of the operation, and this can be rendered insensitive with the aid of ethyl chloride; nevertheless to bear up under the subsequent steps of the operation requires, as a rule, a heroism not found in all patients. The misgivings of all uncertain and imperfect methods of anesthesia are also to be noted with Bloch's method. Anesthetizing the skin incision alone, or following this with general anesthesia, can be replaced by methods more reliable than the application of ethyl chloride.

The use of cold as a local anesthetic can generally be said to be of use for superficial incisions, as in opening an abscess or furuncle, incising fistulæ, aspirating cavities of the body, and minor operations on the skin and mucous membranes. In these conditions, when the skin is frozen, the anesthesia is often insufficient, owing to the deeper tissues being made sensitive by the accompanying inflammation, all pressure and pulling on the tissues causing intense pain.

It is often possible to make simple extraction of teeth more bearable or even painless if the gums on both sides of the alveolar process are

frozen by means of a stream of ethyl chloride. In pulpitis, on account of the presence of great pain, this method is not applicable.

The fact that the chilling of exposed nerve trunks in animals can interrupt the transmission of sensation has encouraged experiments on human subjects, attempting by freezing the skin overlying nerve trunks to produce conduction anesthesia in the area supplied by these nerves. The possibility of so influencing superficially situated nerve trunks can be easily demonstrated by experiments on one's own body.

In one case the ethyl chloride spray was played upon the ulnar nerve at the internal condyle of the humerus. After freezing the skin the spray was continued about half a minute before the nerve trunk was affected. Suddenly intense pain developed in the entire area of distribution of this nerve, followed in about a minute by a feeling of numbness with irregular areas of anesthesia on the forearm and the fourth and fifth fingers. On account of the severe pains it was impossible to continue the freezing to the point of complete interruption of nerve conduction. Two minutes after stopping the ethyl chloride spray no evidence of interruption of nerve conduction remained; nevertheless, at the point of application blisters and a painful infiltrate formed. Experiments with the radial nerve, close to the wrist, proved more successful insofar as the conduction of the nerve could be totally interrupted. It was shown here, as before, that as soon as the cold reached the nerve, severe pains ensued; the skin at the point of application of the ethyl chloride was severely damaged, causing the formation of a painful, slowly healing ulcer.

As before mentioned, the ether spray is more suitable than ethyl chloride when deep action is desired. It requires several minutes to cause interruption of nerve conduction, as for example, in experimenting on the ulnar or radial nerve, the ensuing pains are, as with ethyl chloride, very severe, but the damage to the tissues is avoided. The attempt to anesthetize the finger by the use of the ether spray applied to the base was without result; as soon as the chilling of the tissues penetrated deeply, the pain became unbearable. The practical usefulness of conduction anesthesia produced by freezing the nerve trunks, particularly when applied to the larger nerves, has not proved of much value; however, a reduction of sensibility, if not total anesthesia, can be obtained. Experiments in this direction have been repeatedly made, Rossbach stating that he succeeded in anesthetizing the superior laryngeal nerve and with it the trachea, by applying the ether spray for two minutes to both sides of the neck below the ends of the hyoid bone. Scheller and von Hacker, for the extraction of teeth, do not allow the ethyl chloride spray to act upon the gums, but externally upon the skin, in the region of the anterior surface of the lower jaw, canine fossa, and in front of the ear. Both authors state that an obtunding or total anesthetic effect, sufficient for the extraction of teeth, could be occasionally obtained in this manner, though both acknowledge the uncertainty of the method.

Local anesthesia by means of cold was attempted in other ways, one of which consisted in injecting cold fluids into the tissues. Heinze and

the author have studied the physiological effects produced by the injection of fluids of different temperatures into their own skin in the neighborhood of sensory nerves. We used for this purpose a 0.9 per cent sodium chloride solution, which, injected at body temperature, caused neither irritation nor loss of feeling in the sensory nerves. It was shown that a decided lowering of the temperature of the solution below that of the body produced a corresponding painful irritation, the colder the solution the greater the pain. Reducing the temperature of the solution to 0° or below caused pain, following which anesthesia occurred, lasting a few seconds; whereas solutions of a higher temperature produced absolutely no diminution of sensation. Injecting large areas with solutions at 0° produced more decided effects, as the tissues resumed their normal temperature more slowly. Létang, for purposes of local anesthesia, injected 0.5 to 1 per cent of chloride of sodium at 0° or mixtures of water, glycerin, and ether, but these methods are not worthy of recommendation. For a short anesthesia one cannot expect as much from methods of this kind as from the ether or ethyl chloride spray, the latter causing rapid cooling, never obtained by injecting cold solutions. Létang claimed that by repeated injections the duration of the anesthesia may be prolonged indefinitely. In practice this would be a decided inconvenience and tend greatly to prolong the operation. It has been proposed by Schleich to use cold solutions of cocaine as an injection, but results from this method should not be attributed to the direct action of cold, but rather to a retardation of absorption from the chilled tissues, thus intensifying the action of the cocaine. The use of cold as an aid to various anesthetic agents will be discussed in Chapter VIII.

CHAPTER V.

THE EFFECT OF OSMOTIC TENSION OF WATERY SOLUTIONS INJECTED FOR PURPOSES OF LOCAL ANESTHESIA.

If a glass cylinder, closed at the bottom by means of an animal membrane and filled with a concentrated salt solution, be suspended in a vessel filled with pure water so that the surface of both fluids lie in the same plane, an exchange of molecules wil ltake place between the two fluids, the water passing from the outer to the inner vessel and the salt from the inner to the outer vessel. The former being much stronger than the latter causes the volume of water in the inner vessel to be increased, as shown by the rise of its surface. This exchange continues until the salt solutions in both vessels are of equal concentration. The same exchange takes place when, without the interposition of a membrane, pure water is poured over a concentrated salt solution. In the latter case we speak of a diffusion, in the former of osmosis or osmotic diffusion. The energy causing the exchange of molecules and the rising of the surface of the salt solution in the suspended vessel is called osmotic pressure or osmotic tension. This is an intrinsic latent physical property of water and all watery solutions, and is dependent upon the number of molecules per liter and their degree of dissociation. The rapidity of diffusion of the salt solution has a definite relation to the character of the dissolved substances, the concentration of the salt solution, and the permeability of the separating membrane. The rapidity of diffusion of the water toward the salt solution is almost in proportion to the concentration of the latter and increases with a rise in temperature. The rapidity of movement of the salt solution is less dependent on change of temperature. Colloids, albumin, mucus, glue, rubber, etc., diffuse with difficulty and sparingly through dead animal membranes as opposed to the crystalloid substances and do not alter the osmotic pressure of the fluids in which they are dissolved. If, instead of pure water and a salt solution, a weak and a concentrated solution of salt are so placed as to act one upon the other, a movement of water takes place from the weaker to the more concentrated solution, the salt passing in the opposite direction. The rapidity of exchange will in this instance, other things being equal, be proportionate to the difference in concentration of the two solutions.

When solutions of different salts are placed together one will find in each a solution of the other salt, but inasmuch as there is no interchange of water the concentration of the solutions is not altered. Solutions having the same osmotic pressure are called isosmotic or isotonic; if one of the solutions be diluted by the addition of water, it is said to be hyposmotic or hypotonic, and gives off water to the more concentrated solution; if the solution be made more concentrated, it is called hyperosmotic or hyper-

tonic, and absorbs water until both solutions are again isotonic. An interchange of the molecules of different salts in solution occurs at the same time, and independently of the movement of water, even if the solutions be isotonic, so that eventually the salt molecules on both sides will be equal. These osmotic changes are constantly taking place throughout Nature, wherever living cells and body fluids come into contact with one another. The *modus operandi* by which the organism maintains a constant and definite salt content in the body juices, under normal conditions, has recently been given much study and bids fair to be of great significance in future pathology and therapy.

The proper functioning of nerve elements, in fact all living tissues, is known to be dependent upon their being immersed in a nutritive solution, consisting of water, albuminous substances, and salts. The composition of this solution must not only be of definite chemical and physical constancy, but likewise of definite temperature and concentration of its salt content, etc., as determined by its osmotic pressure.

The concentration of the salt content varies in different animals and plants. It is of much interest to know that living tissues, especially nerve elements, can be kept alive in certain watery solutions having a definite salt content, without otherwise corresponding in their chemical composition to the nutrient fluids, so-called physiological solutions, whereas slight changes in the salt content occasion a rapid loss of function and change of form of the tissues. The cause of these conditions is dependent upon the presence or absence of osmotic tension between the salt solution and the body fluids. The solutions in which the form and function of the tissues is best preserved are those which are isotonic with the normal nutrient fluids.

Nasse was the first to make experiments in this direction. By placing the muscles of frogs in salt solutions, he demonstrated in which concentration their irritability was longest preserved. Solutions found to be best suited for this purpose were solution of 0.6 per cent sodium chloride, 1.75 per cent solution of sodium iodide, 1 per cent solution of sodium nitrate. These solutions and frogs' blood have almost the same osmotic pressure.

De Vries was the first to accurately describe isotonics. He determined the isosmotic concentration of a large number of organic and inorganic combinations, and studied their relations to molecular weight. The discovery of isotonicism resulted from the observation that watery solutions of whatever composition, but of definite concentration, produced phenomena in plants which could only be caused by dehydration (plasmolysis) of plant cells and young sprouts. The weakest concentration of solutions able to produce the above described dehydration are said to be isotonic to one another.

In a similar manner, Hamburger, Koeppe and Hedin, by physiological experiments with the red corpuscles of various animals and man, noted the swelling and dehydration of the corpuscles under the microscope, and in this way were able to determine the isotonic concentration of aqueous solutions. Hamburger determined first the concentration in which the

red-blood corpuscles were most quickly and completely precipitated, and the weakest concentration causing hemolysis; the mean of these two values being identical with De Vries' results regarding the isotonic concentration of the various salt solutions. Koeppe and Hedin by certain special methods, made use of the volumetric change in the red corpuscles for the determination of the isotonicity of solutions; with hypotonic solutions the volume being increased, and with hypertonic solutions diminished in volume. These interesting physiological methods are used very seldom today, as physical chemistry has devised simpler and more exact methods for the determination of osmotic tension of fluids.

Osmotic tension is most easily determined by finding the freezing-point of water holding crystalloid substances in solution. Solutions having the same freezing-point are called isomotic. Osmotically indifferent, in reference to the absorption and giving up of water in their action upon human tissues, are those solutions having the same freezing-point as the normal body fluids, for example, the blood. The determination of the freezing-point of human blood, lymph, transudates, exudates, were first made by Dreser, later by Hamburger, Koranyi, Tauszk, Winter, and the author. The determination of the freezing-point of the blood has of late become an important method of clinical research.

The freezing-point of the blood of healthy individuals was found by Dreser to be —0.56°; Hamburger, —0.55°; Koranyi, —0.56°; Winter,—0.55°.

The mean freezing-point of the blood is held by most investigators to be —0.56° although the mean value as determined by some is placed at —0.555.° Variations from these figures, above or below, are exceedingly small under normal conditions. Values of —0.54° and —0.57° can hardly occur in healthy individuals; in certain diseases variations of a few hundredths of a degree above or below are noticed.

Watery solutions, therefore, with a freezing-point of —0.55° to —0.56° have approximately the same osmotic pressure as human blood. Solutions with a freezing-point near 0° are hyposmotic, those with a lower freezing-point than —0.55° are hyperosmotic, compared to the nutrient fluids of the human body. Monocellular plants and animals can live in water without tumefaction of their structure or undergoing any change of their salt content by reason of the structure of their encapsulating membrane. In the same manner epithelium of the skin and that of most mucous membranes protects the human tissues from the action of solutions of varying osmotic pressure. If such solutions, however, are brought into intimate contact with wounds or injected into the tissues, osmosis will take place, according to the physical experiments previously mentioned with plant cells and red-blood corpuscles, resulting in their change of volume. Hyposmotic solutions cause cells and other tissue structures to swell, hyperosmotic solutions by their dehydrating action cause them to shrink, producing what is called plasmolysis. The more the solutions vary in their freezing-point from that of the blood, the greater the osmotic change in the tissues.

Tumefaction as well as dehydration influences the action of the sensory nerves and injures the tissues irrespective of the substances in solution. Experiments have been carried out by the author and confirmed by Heinze in reference to the physiological effect of the differences of osmotic tension. For this purpose injections of lukewarm water and salt solutions of varying degrees of concentration were injected into his skin and that of other subjects. If a fluid is injected into the dense tissues of the skin by means of a needle passed parallel to its surface, avoiding the loose subcutaneous connective tissue, a round, pale wheal raised above the surface of the surrounding skin will be immediately apparent. Changes of sensation in this wheal, produced by the injection of a foreign fluid, can be readily tested in consequence of the rich nerve supply of the skin. Wheals produced in this manner were first used by Schleich, but the credit for the practical adaptation of this method must be given to Heinze. The observations made by Schleich upon the skin wheal have been proved very indefinite by control experiments made by many others. The results of our experiments are shown in the table (Fig. 4).

On the horizontal line chloride of sodium solutions are noted, varying in strength from 0 per cent (water) to 10 per cent; the freezing-point for a number of these solutions is also shown. The curve designated by the solid line denotes sensory irritation, evidencing itself as pain when the solution is injected into the skin; the dotted curve represents paralysis of sensation, anesthesia having followed the irritation. Points on the curve denote the relative intensity of irritation and paralysis. Salt solution of 0.9 per cent occupies a middle position in the chart having a freezing-point of −0.55° and therefore having about the same osmotic tension as the human blood. All solutions placed to the left of this point cause swelling of the tissues, those to the right causing dehydration. If a 0.9 per cent solution of lukewarm sodium chloride is injected into the skin neither pain nor irritation follow, there is no alteration of sensibility in the skin of the wheal, at least there is no diminution of sensation, the wheal disappearing in a short time without leaving any evidence of its previous existence. If the concentration of the solution is now reduced to 0.55 per cent pain occurs upon injection, which is increased upon a further reduction of the strength of the solution, becoming very severe when pure water is used. The pain following these injections is called the pain of tumefaction, which is of short duration, followed by a diminution or loss of sensation in the area involved. It is increased in intensity and duration by a reduction of the concentration of the solution. The use of pure water causes anesthesia of the longest duration, lasting about fifteen minutes. This is called tumefaction anesthesia. Weak salt solution may cause damage to the tissues, painful infiltrations remaining; pure water frequently causes superficial necrosis, so-called tumefaction necrosis. With the use of solutions containing more than 0.9 per cent of sodium chloride, symptoms of dehydration will be noted such as irritation, paralysis, or damage to the tissues. The irritation from this solution is quite different from the pain of tumefaction. It follows a comparatively painless injection lasting several minutes, the wheal becom-

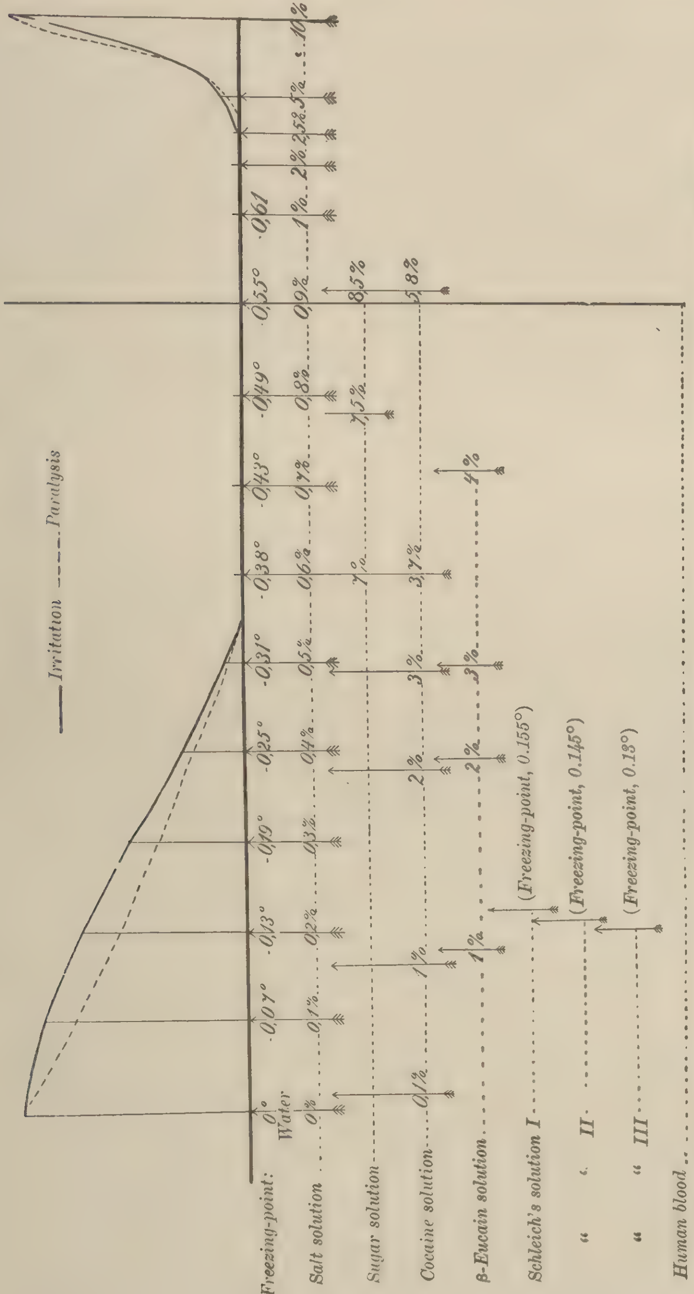


FIG. 4.—Irritation and paralysis curves, showing the effect of osmotic tension of water solutions on nerve substance.

ing markedly hyperesthetic, and is then followed by anesthesia. During this time the swelling undergoes peculiar and typical changes of form. With the subsidence of the burning pain and the beginning of anesthesia, the wheal sinks quickly in the center, the margins remaining elevated in the form of a circular ridge. The anemic center and surrounding margin are separated by a narrow red ring. In about fifteen minutes the swelling flattens out uniformly, extending from the center toward the periphery, and sensation gradually returns. Concentrated salt solution furthermore injure the tissues. The intensity of all these phenomena increases with the concentration of the salt solution. They are noticeable at 2.5 per cent and more than 10 per cent salt solution can hardly be borne. In the diagram on each side of the 0.9 per cent salt solution, is noted the so-called indifferent zone in which a number of solutions from 0.55 to 2.5 per cent do not produce noticeable swelling or dehydration of the tissues, or any of the symptoms above mentioned. The curve indicating pain and paralysis naturally does not represent absolute values, and was determined by experiments carried out upon the skin of our forearms. When salt solution is injected into the tissues of very sensitive persons, or into hyperesthetic areas, weak solutions must be used to avoid swelling or dehydration of the tissues. In this manner the pain and anesthesia curve will approach the horizontal, nearer to the middle point than has previously been shown, and the indifferent zone will be narrower.

That these are the real symptoms of tumefaction and dehydration we may conclude from the following circumstance. Inasmuch as water and salt are constantly present in the body and act chemically upon the tissues very slightly, we must consider the pain, paralysis, and injury to the tissues as due to the physical properties of the solution. The symptoms must be due to the osmotic tension of the solutions, as the symptoms vary with the change of osmotic pressure and disappear when osmotic tension between the blood and the solutions is equal. There are a number of other salts which chemically react slightly or not at all upon the tissues. To these belong most of the sodium salts, as phosphates, carbonates, and borates, also sugar and some of the urea compounds. The solutions of these salts have been examined systematically in the foregoing way, and found to have, like the chloride of sodium, an indifferent zone as determined by the freezing-point, isotonic with the blood or physiological solutions, and that their solutions produce the same symptoms as salt solutions with a like freezing-point, from tumefaction pain to the peculiar change of form of the wheal due to the strong dehydrating actions of the solutions. For this reason the curves for irritation and paralysis are applicable for watery solutions of all substances. The symptoms of their physical effect are often obscured in consequence of their difference chemically, irritating or paralyzing the sensory nerves, damaging or destroying the tissues. It is in this case necessary to find the freezing-point of the solution, in order to determine physical effect upon the tissues.

In Fig. 4 the freezing-points of watery solutions of a few other salts are charted in their respective positions. We see that the physiological concentration of cane sugar is about 8.5 per cent. This solution is totally

indifferent and causes upon injection neither pain nor anesthesia. The solutions frequently used for injection beneath the skin are very dilute and must necessarily cause pain, owing to the differences in osmotic tension. The table shows, furthermore, the freezing-point of several anesthetic solutions to which we shall return later.

A few historical observations will now be added.

For a considerable period of time, ever since anatomical and physiological studies were followed, it has been known that water itself has the elements of a protoplasmic poison, that it destroys the structure of those cells not protected by an impermeable membrane. The injurious effect of swelling can be observed under the microscope; the tissues saturated with water increase in volume, lose their structure, the sarcolemma of muscle fiber ruptures, and nerve fibers are completely destroyed. This change of form or total destruction of tissue was long known to the older anatomists. It has also long been known to physiologists that the function of the tissues is destroyed by swelling consequent upon immersion in water or by their desiccation. Concentrated salt solutions can likewise injure the tissues by their dehydrating action. Fresh muscles when placed in water lose their properties of contraction and response to stimuli, becoming rigid (Swammerdam).

Tumefaction and dehydration, when affecting a nerve trunk, act as an irritant and lower its excitability. Water injected between the fibers of a nerve trunk at once interrupts conductivity and seriously injures it (Biberfeld). The fact that these phenomena failed to appear when definite quantities of salts were dissolved in the water led finally to the discovery of the isotonicity of solutions and their connection with the molecular weight of the dissolved body. This was of far-reaching importance to theoretical chemistry, and van t'Hofft's theory of solutions is dependent upon this work of De Vries and Hamburger.

Saturating the body of animals with water causes severe general symptoms, in consequence of the diminution of osmotic tension of the blood and body fluids. According to Falck, dogs are killed by the intravenous injection of 88 cc of water per kilo of body weight. Subcutaneous injections of about 200 cc of water cause death in rabbits, with symptoms of difficult respiration, impaired heart action, subnormal temperature, convulsions, and hemoglobinuria (Falck, Emmerich). Custer made the same observations upon injecting rabbits subcutaneously with large quantities of a very weak cocaine solution. The animals died, not as a result of cocaine poisoning but in consequence of the absorption of water, a consequence which could have been avoided by the addition of salt.

The prevailing opinion seems to be that a 0.6 per cent salt solution is the most suitable fluid to use in connection with the tissues of the body and has therefore been called physiological salt solution. Hamburger and Koeppe called attention to the fact that this solution, used in the previously mentioned experiments of Nasse on frog muscles, still produced tumefaction, while a salt solution of 0.92 per cent produced the same osmotic tension as the human blood. A 0.6 per cent salt solution is therefore physiological for frogs and a 0.92 per cent salt solution is physiological for man.

The observation that the subcutaneous injection of water relieves pain has been verified by many. The first of these observations dates from Potain (1869) and Dieulafoy (1870). Lafitte states he has achieved good results in various painful affections, as sciatica, neuralgia, and rheumatism, by water injected directly into the affected part; the occurrence of severe burning pain, though of short duration, was the only unpleasant feature. The soothing effect he ascribed to the compression produced by the injected fluid or to the imbibition of water by the sensory nerve fibers, whereby the latter momentarily lost their ability to receive and transmit their impressions. Similar communications have been received from Lelut, Burneys, Yes, and Griffith.

Liebreich and Schleich have observed that water produced irritation, to be followed by anesthesia, likewise the indifference of these solutions upon the addition of salt, and finally the anesthetic action of very concentrated salt solutions.

Under the guidance of Liebreich, Bussenius conducted animal experiments in order to determine the local anesthetic effect produced by different substances. He injected these solutions subcutaneously into rabbits and found that while 0.6 per cent chloride of sodium solution produced no alteration of sensation, 5 per cent and 10 per cent solutions did so to a slight degree. We have shown above that more exact results can be obtained by experimenting on one's own body, using Schleich's method. Schleich believed that there must be a solution of such concentration between pure water and a 0.6 per cent salt solution which would not provoke pain upon injection, but on account of similarity to pure water it would later produce anesthesia, and he thought that he had found a useful anesthetic in the 0.2 per cent salt solution. The anesthesia and pain of tumefaction are always associated with one another. If the tumefying action of the water is reduced, the pain is lessened and the anesthesia is unsatisfactory.

Tumefaction anesthesia has been seldom used in performing operations; it has been occasionally attempted by Halstead and Gant. Schleich reports that he has been able with the aid of injections of water to excise a carbuncle painlessly. Isolated attempts were later made by him to produce local anesthesia by the injection of 0.2 per cent salt solution. The injection of this solution is always very painful, its consequent anesthesia imperfect, and of very short duration. An anesthetic which necessitates pain for its induction has been called by Liebreich "anesthesia dolorosa." Tumefaction anesthesia can be called an anesthesia dolorosa, and owing to its injurious action upon the tissues is practically useless. The results of our researches concerning the physical by-effects of watery solutions may be classified in the following manner:

Injections into the tissues for whatever purpose must be composed of fluids of the same osmotic tension and freezing-point as the body fluids. Inasmuch as solutions for local anesthesia must be used more dilute than their physiological concentration, a corresponding quantity of an indifferent salt, as sodium chloride, must be added to prevent any injurious action upon the tissues.

CHAPTER VI.

ACTIVE AND INDIFFERENT SUBSTANCES. ABSORPTION AND LOCAL POISONING. TESTS, GENERAL PROPERTIES, AND METHODS FOR USING LOCAL ANESTHETICS.

In the preceding chapter we studied the effect of certain substances which did not produce noticeable changes in the tissues, thereby making possible a study of the physical effects of their watery solutions when injected into the tissues. Let us now consider the ultimate fate of these substances when injected into the tissues. A small part may find its way at once into a vein or lymph space and be quickly taken up by the circulation; the larger part, however, remains at the point of injection, being slowly absorbed after a more or less extensive diffusion into the surrounding tissues without causing any noticeable local change.

When osmotic differences of tension are present there is a tendency on the part of the body to equalize them, at least the interesting investigations of Hamburger regarding the absorption of watery solutions from serous cavities seem to support this theory. In this connection Hamburger noticed the following: (1) Serous fluids and salt solution placed in the abdominal cavity of animals are absorbed. (2) These fluids do not change the osmotic tension of the blood of the animal when isotonic. (3) Hypotonic and hypertonic solutions become isotonic in the abdominal cavity during absorption. (4) While present in the abdominal cavity there is a molecular exchange between the solution and the blood plasma.

After the injection of an isotonic 1.7 per cent solution of sodium sulphate into a rabbit, a considerable amount of chloride of sodium, sodium phosphate, and albumin are found in the remaining isotonic solution. Hamburger's experiments do not show that the absorption of the dissolved substance is delayed when differences in osmotic tension between the solution and the blood plasma exist. Hamburger expressly states that the equalizing of the pressure differences takes place during but independent of the absorption. This is not without practical interest, because it has been erroneously assumed (Legrand) that cocaine is absorbed more slowly from hypotonic than isotonic solutions, and that for this reason the use of isotonic solutions is of no particular advantage.

The investigation of Schnitzler and Ewald likewise show that the rapidity of absorption is dependent upon the concentration of the salt solution. It can be shown that a definite quantity of a salt (iodide of potash, salicylic acid) is more rapidly excreted by the kidneys, and therefore more rapidly absorbed the more concentrated the solution introduced

into the abdominal cavity. The great rapidity with which substances introduced into the abdominal cavity reappear in the urine verifies the important observations made by Klapp, Heidenhain, Orlow, Starling, Tubby, O. Cohnheim, and others, that the absorption from serous cavities of substances dissolved in water takes place principally through the circulation. The authorities mentioned, contrary to the belief of Hamburger and Cohnstein, hold it as undoubtedly proved, that in addition to osmosis, and filtration under increased intraperitoneal pressure, the vital forces of the living abdominal wall play a leading part, and must influence the merely physical processes concerned in the absorption from the abdominal cavity.

The phenomenon of absorption of injected watery solutions from the subcutaneous connective tissue does not differ materially from what takes place in the abdominal cavity. Independent of the water, which causes swelling or shrinking of the tissues, an interchange of molecules takes place between the salts in the solutions and the tissue fluids, as in a physical experiment. In fact, an osmotic indifferent salt solution is, in this respect, not entirely indifferent, as the tissue fluids contain other substances than salt; in fact, Hamburger found that the red-blood corpuscles will give up their coloring matter in such a solution. According to Hoeber's observations, an isotonicity of the body fluids would be temporarily disturbed by this solution. The amount of the dissolved substance diffused in the region of injection in a unit of time must be dependent upon the concentration of the solution and the diffusibility of the substance which in turn is influenced by the varying permeability of the membranes and skin with which it comes in contact. If the injected solution be under great pressure, it will by means of simple filtration escape into the surrounding tissue. The process by which finally the largest part of the dissolved substance as well as the solvent enters the circulation, that is, absorption, is surely a vital process; it is associated with the vitality of the tissues, taking place slowly in those with impaired vitality, much more quickly in the presence of active metabolism, and entirely absent in lifeless tissues. It is an established fact that watery solutions absorbed from the subcutaneous connective tissue enter the circulation in largest part without the assistance of the lymph vessels (Magendie, Lebkuechner, Asher, Munk, Hamburger); whereas, on the other hand, oily solutions are almost entirely absorbed by the lymph vessels, in consequence of which absorption takes place more slowly.

Opposing the previously mentioned indifferent, or almost indifferent, substances, solutions of which exert a physical reaction on living tissues, are an endless number of other substances which cause other than physical changes in the tissues, due to their chemical composition. All of these changes may be grouped under the head of local poisoning and give evidence of their presence in the living body by an increase, a disturbance or loss of function, stimulation or paralysis of sensory nerves, tissue injury, or local death. These symptoms are sometimes transient, that is, after a certain time the living tissues are able in some way or other to dispose

of the foreign substances affecting function or threatening the life of the structure and again take up their former activities practically unchanged. In most cases the local poisoning causes permanent changes resulting in a more or less severe injury, inflammation, or necrosis of the tissues. The majority of all active substances cause the tissues at the seat of their activity to become hyperemic, some do not appreciably change the blood-content, some few induce a contraction of the bloodvessels and make the tissues anemic. Many finally bring about, immediately following their application, peculiar transient local edema, a symptom at once recognized by anyone remembering the effects of insect bites.

The process of absorption must progress differently with active than with inactive substances, as the local changes as described can hardly be conceived without a loss of substance; a local action can, as a rule, only take place when a portion of the active substance is chemically combined with the structures in the immediate locality and is thus prevented from being carried into the circulation. What ultimately becomes of this portion of most substances is unknown. Concerning certain alkaloids, it is known that after their incorporation with the living tissues they are not absorbed in their original form, but that the organism eliminates them by disintegration; cocaine and suprarenin belong to this group. In this manner the living body is freed from poison. The more slowly a substance is absorbed from the place of application the more thorough is the permeation of the tissues, and the more intense and extensive the local action then when more quickly eliminated by a rapid absorption. It is therefore of importance for us to study the methods of producing a retardation of absorption as an important aid to local anesthesia.

When chemically active substances are brought into contact with sensory nerves, they invariably bring about a transient or lasting paralysis, namely, anesthesia, usually preceded by a state of severe irritability. Some few substances have been found which produce local poisoning with transient sensory paralysis, without irritation or injury to the tissues. These are the substances useful in the practical application of local anesthesia.

The research methods having for their object the determining of the local anesthetic properties of various substances are uncertain because of the fact that the local anesthetic power of a substance is dependent in large measure upon the place and method of application. The first attempts in this direction were associated with the belief that if inhalation anesthetics were brought into direct contact with the nerves that they would have the same action as when carried to the brain through the circulation. It was found that ether and chloroform interrupted the conductivity of an exposed nerve when acting upon it in the fluid or gaseous state (Longet, Bernstein, Ranke, and others). This property is shared by many other non-anesthetic substances, as the function of a nerve is dependent upon its saturation with a fluid of a definite composition.

Much experimental work in reference to chemical stimuli and their connection with the composition of chemical compounds is being under-

taken by physiologists (Gruetzner). These studies are of no importance to local anesthesia.

Liebreich and his pupils, Bussenius, Muellerheim, and Kunowski, were the first to systematically experiment with a number of organic and inorganic compounds in reference to their local anesthetic properties. Those substances not already fluid were dissolved and injected subcutaneously or placed in the conjunctival sac of guinea-pigs, rabbits, and frogs. Sensation was then tested by pricking with needles, irritating the cornea, or by using Tuerck's test. The subcutaneous tissue is not very suitable for such experiments, as it is not sufficiently sensitive, and inasmuch as it is not situated upon the surface of the body, it is not possible to determine the disturbance of sensation from the substance injected, but only that of the overlying skin. Notwithstanding the uncertainty of this method the above-mentioned authors found that by far the most of the anesthetic or non-anesthetic substances which they tried did not leave sensation intact, but were, according to Liebreich, "anesthetica dolorosa," that is, irritating before anesthetizing.

The anesthetica dolorosa are found to be more numerous when dilute chemical solutions are used in connection with the Schleich wheal on the bodies of persons suitable for experimentation. Only after we knew the physiological effect of tumefaction and dehydration and the determination of the osmotic pressure of the solutions in question as described in the foregoing chapter was it possible to place an experimental value on these methods. The solution must have a freezing-point similar to that of blood, due either to the active substances contained in it or made so by the addition of indifferent substances. In studying the differences of osmotic tension between the tissue fluids and the injected solutions, we have already determined that this difference alone can interrupt sensation. The specific action of a substance dissolved in water should therefore be studied when the solution is osmotically indifferent. With the aid of the wheal and a consideration of the facts just mentioned, Heinze and the author found that there were few chemically indifferent, or almost indifferent, compounds which upon contact with the sensory elements left sensation intact. Most substances are active, but only a few of these are able to temporarily influence the function of sensory nerves without severe irritation and damage to the tissues. By means of the wheal on the human body it is possible to determine relative if not positive values as to the local anesthetic properties of a substance.

This may be determined, first, by finding the lowest possible concentration of a substance in solution which will produce a local anesthetic effect. This is done by using constantly weaker solutions, making allowance for the difference in their physical characteristics. The weaker the solution the greater must be the affinity of the substance for the protoplasm of the tissue cells, that is, its local anesthetic power. All of our so-called local anesthetics are characterized by their ability to influence nerve substance in very dilute solution.

The second means at our disposal consists in the approximate deter-

mination of the duration of anesthesia by producing several wheals next to one another upon the skin of the person to be experimented upon by the injection of the same quantity of solutions of like concentration, that is, equimolecular solutions. The longer the duration of anesthesia, the more lasting must be the changes which this agent produces on the nerve substance. The duration of anesthesia is dependent upon many other circumstances, such as the nature of the person experimented upon, the quantity of blood in the part, the location of the part experimented upon, the rapidity of absorption, and the concentration of the solutions.

On the plainly visible skin wheals other tissue changes may be readily noticed. For instance, it can be readily determined whether the wheal disappears rapidly and completely, showing that the substance was absorbed without local tissue damage, or whether painful infiltrates remain which may undergo inflammation or necrosis, or whether the blood-vessels dilate or contract. Following experiments with codeine, morphine, peronin, and tropacocaine upon the skin, an acute local edema occurs resembling that of insect poisoning. In this manner substances can readily be tested and compared in their action with other substances without danger to the individual experimented upon, provided very dilute solutions are used at the start. The results of such investigations can be at once put to practical use. When the solution of a substance is not brought into immediate contact with nerve elements by injection but reaches it indirectly by diffusion, then the local anesthetic effect cannot be determined alone by the above-mentioned experiments, but will depend upon this permeability of the membranes with which it comes in contact, and the diffusibility of the substance. Thus a substance having pronounced anesthetic properties may become useless because unable to diffuse through a membrane or layer of tissue and reach the nerve elements. Cocaine having marked local anesthetic properties is ineffective when placed upon the skin, as it cannot penetrate it while a similar application of dilute solutions of carbolic acid which have only slight anesthetic properties cause a marked diminution of sensation. A comparison of various substances previously shown to be harmless can be obtained by observing the extent of anesthesia as affected by the process of diffusion if solutions of like strength be injected into the subcutaneous cellular tissue in the region of the nerves of the skin and noting the duration and extent of the anesthesia in the area of distribution of these nerves. Recke has taken up the very important comparative study of the newer substitutes for cocaine along the lines mentioned above; the results of his work will be referred to later. Hoffman and Kochmann have recently made use of the wheal as a means of determining the comparative value of different local anesthetics. They put in calculation another important factor, the general toxic effect of the substance. As a result of their experiments, they give the following simple formula:

$$W = \frac{1}{K} - L$$

in which W indicates the anesthetic value of the substance. K the weakest concentration in the percentage of solution that will still produce anesthesia and L the lethal dose. Gradenwitz has determined the relative values of the local anesthetic power of chemical compounds in their actions on the skin of a frog. His method of procedure was as follows: The brain, medulla oblongata, and heart were removed from frogs, the blood was washed from the vessels, the object being to prevent the general absorption of the substances and thus isolate their local action. The solution to be tested was brushed upon the left leg of the frog, and after being allowed to act for a definite length of time was washed off. Both legs were then immersed in a $\frac{1}{6}$ per cent hydrochloric acid solution, according to the direction of Tuerck, and the condition of the reflexes tested. Four distinct phenomena were recognized: (1) Both legs were simultaneously drawn up; the substance was ineffective. (2) After a short time the left leg was drawn up; the substance had increased the sensibility. (3) The right leg was drawn up sooner than the left; the sensibility of the left leg was diminished. (4) The left leg was not drawn up; sensation was absent. This last experiment was controlled by immersing the legs in a 25 per cent hydrochloric acid solution.

The results of the investigations of Gradenwitz apply only to the skin of the frog, the physiological properties of which must materially influence the local action of the substance. It was particularly noticeable that stimulation of any sort was practically never observed even with substances which, according to the investigations of the pupils of Liebreich and the writer, must be classed as anesthetica dolorosa. The practical application of the observations of Gradenwitz and a comparison of their value with other methods of investigation is not possible so long as the permeability of frogs' skin for various substances is unknown.

A different sort of animal experimentation was advised by Loewy and Mueller for the testing of yohimbin, a supposed new anesthetic. If animals are allowed to inhale vapor of ammonia, expiratory paralysis at once takes place, due to irritation of the trigeminus fibers in the nasal mucosa. If the nasal mucosa is previously anesthetized the action of the ammonia is diminished, that is, respiration becomes slower, more superficial, or may cease. To those who have had experience in animal experimentation the difficulties of obtaining exact result in testing sensation are well known.

Important results, to which we will repeatedly refer, have been obtained through the researches of Laewen and Gross. They allowed the anesthetizing solutions to act directly upon the sciatic nerve of frogs and, after observing their effect upon the motor excitability of the nerve, compared results with those obtained in the wheal experiments.

It has been shown that the anesthetic property of various chemical compounds is associated with certain groups of atoms inherent in the molecule, which Ehrlich has termed the anesthesiphore. The other groups of atoms can be readily replaced in the construction of new anesthetic substances. Experiments along these same lines resulted later in

the discovery of salvarsan by Ehrlich. After the discovery of the chemical composition of cocaine with its atomic grouping by Einhorn, the synthetic preparation of this alkaloid became possible and served as a starting-point for interesting experiments in combining the anesthesiphore atomic group with new atomic groups. This chemical research resulted in the discovery of a number of new local anesthetics, such as holocaine, eucaine, and those of the orthoform group; later, stovaine, alypin, and novocaine—certainly a triumph of an exact science. In regard to the chemical relation of these substances to one another, the reader is referred to Einhorn's comprehensive compilation.

The previously discovered practical local anesthetic substances have the following properties in common. Like all narcotic substances they are all protoplasmic poisons, paralyzing not only the nerve elements but the function of all protoplasm with which they come in active contact. This action they possess in common with many other active substances, even with the physical action of water upon the protoplasm. Their intense selective affinity for nerve substance is particularly characteristic. They paralyze the function of nerve tissues with which they come in active contact in solutions too weak to appreciably influence other kinds of protoplasm. These substances, when introduced rapidly and in sufficient quantity into the circulation, besides their local effect, produce general symptoms of poisoning. The affinity of these substances for nervous tissue makes them particularly toxic to the central nervous system.

It is of practical importance to remember that these secondary symptoms are not dependent upon the dose used, as local anesthetic substances have no so-called maximum dosage, but rather upon the rapidity with which they are introduced into the body and absorbed from the same. This will be discussed more in detail in the following chapter on cocaine.

Local anesthetics are further characterized by the fact that the changes which they produce in the tissues readily return to normal. They are able to temporarily interrupt nerve function without any permanent injury remaining, being thus distinguished from Liebreich's anesthetica dolorosa which cause irritation before paralysis, followed by injury to the tissues.

Gross summarized the above-mentioned experiments regarding the general properties of local anesthetics in the following manner: The base of local anesthetics (cocaine, novocaine, stovaine, eucaine, and alypin) all have a more intense action than their salts, for the reason that basic local anesthetics acted more quickly and in weaker solutions than their salts. The anesthetic potential of a local anesthetic salt is dependent upon the anesthetic potential of the base and upon the hydrolytic dissociation of the solution. The difference in action of solutions containing the chloride salts of the local anesthetics in general use is shown to be dependent upon the degree of hydrolytic dissociations of the solutions. The weaker the salt-forming power of an acid the greater the hydrolytic dissociation of the solution; thus the activity of a solution of a local anesthetic salt is greater the weaker its acid radical; for example, a novocaine-

bicarbonate solution is five times as active as an equimolecular novocaine-chloride solution. The sensory nerves, as has been shown with cocaine, (see page 83) are more sensitive to the action of local anesthetics than the motor nerves. According to the author's experiments and experience the observed effects on motor nerves cannot be accepted as applying equally to sensory nerves and to the practice of local anesthesia. He has never been able to convince himself either by wheal experiments or by the injection of nerve trunks on his own body that novocaine-bicarbonate is more effective than novocaine-chloride. The best method for the comparative investigation of local anesthetics at the present time is the wheal experiment.

Following the experiments of Meyer and Overton on anesthesia, Gross attempted to explain the processes underlying anesthetic action. They maintain that anesthetics act upon the lipoid substance of the central nervous system. Anesthesia, therefore, depends upon the fat-dissolving power of the drug; the more powerful the anesthetic the greater is its ability to dissolve fat, so-called splitting coefficient—that is, the relation between their fat-dissolving power and their water-dissolving power. In consequence of their strong solvent action on fat, anesthetics accumulate in the central nervous system where, according to Meyer and Overton, they do not enter into chemical combination, but only bring about a physical change in the lipoids, forming a fixed solution, as it were. According to Gross this theory has a corresponding value for the action of local anesthetics on the peripheral nervious system.

Verworn, Buerker, and others, though not denying the theory of Meyer and Overton regarding the relation of anesthetics to the lipoids, nevertheless hold to the older theory that anesthetic action is due to the formation of chemical compounds in the central nervous system. Both maintain that anesthetics act by depriving nerve substance of oxygen, causing a temporary suffocation, combined with paralysis of their physiological function. The fact that a portion of the anesthetic remains at the place of application and does not enter the circulation before being destroyed, seems to favor the chemical theory, at least for local anesthetics. Leaving out of consideration the finer changes in nerve tissue resulting from general and local anesthesia without detracting from our present knowledge, we may mention the older theory of Preyer, who stated that general and local anesthetics produce changes in the central nervous system and peripheral nerves, causing a temporary loss of function of the cells, for the restoration of which their entire vital energy is necessary.

Before taking up for consideration the various local anesthetic agents, it is important for us to know in what way their application produces terminal and conduction anesthesia in man.

The schematic cross-section (as shown in Fig. 5) represents the surface of any part of the body, the line $A-B$ representing skin, mucous membrane, serous membrane, or synovial membrane, on the surface of the body, or lining one of its cavities. N_1 and N_2 represent two sensory nerve trunks ramifying in the tissues, and as usual overlapping one another in their

area of distribution, so that a certain area is innervated by the terminal branches of several nerves. We shall now attempt to anesthetize the circular area marked *I* with an active anesthetic substance. Area *I* can be rendered insensitive by bringing the sensory endings in contact with a sufficient quantity of an anesthetic which will inhibit their function. This is called terminal anesthesia and can be brought about in several ways.

1. A solution of an active substance is injected into the tissues under slight pressure, so that area *I* is thoroughly saturated with the solution, replacing the normal tissue fluids. The molecules of the dissolved substance, mechanically injected, immediately come in contact with the tissue elements and promptly give evidence of their uniform action in the entire area. A chemical action will also be observed when the solution is diluted to the lowest limit of activity of the dissolved substance; this

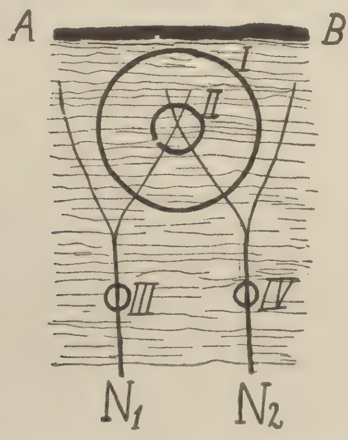


FIG. 5.—Schematic diagram of the methods of local anesthesia.

type of infiltration is seen in the skin wheal and had been designated by Schleich as infiltration anesthesia. The duration and intensity of this anesthesia is in proportion to the change produced in the nerve substance and the strength of the solution. The more concentrated the solution the longer the duration of the anesthesia. The duration and intensity of the anesthesia is the same in the entire area, as the nerve elements have been equally affected.

2. In the area designated in the figure by *I*, other methods can be employed for producing terminal anesthesia. If an anesthetic solution be injected in the center of the area represented by *II* in the diagram the same local conditions will occur in this area as have been mentioned for infiltration anesthesia. Whether the solution has the same or different osmotic pressure than the blood, there now takes place an exchange of molecules between the dissolved substance and the salts in the tissue fluids. The former diffuse with more or less rapidity, depending upon

their diffusibility, the permeability of the membranes surrounding the area, and the concentration of the solution, affecting the tissues after a certain time in the entire area designated in the diagram by *I*, producing the same symptoms as originally took place in the center of the area designated by *II*. A difference, nevertheless, exists, as the solution during the process of diffusion becomes constantly more dilute, containing less of the active substance owing to portions of it being combined with the tissues the farther it is removed from the place of injection: In consequence of which in a given case the intensity of anesthesia will diminish from center toward the periphery in the area marked *I* in the diagram. The action by diffusion of a substance can scarcely be expected if the solution is so dilute that the dissolved substance is only sufficient for producing anesthesia in the area infiltrated, the number of molecules capable of diffusion into the surrounding tissues being too small to be effective. It is therefore necessary that small quantities of a concentrated solution be used to produce in this manner a local anesthetic effect the same as though the entire area designated *I* had been infiltrated. This is the so-called indirect infiltration anesthesia.

An anesthetic solution when placed upon the surface *A–B* can, by means of diffusion, reach the nerves in the area designated *I*. Local anesthetic action can, however, only occur when the protecting membrane is permeable to the solution, and the solution much more concentrated than that used for injection.

Local anesthetics can affect the function and conductivity of nerve trunks at points remote from their area of distribution as when solutions are injected in the region of the nerve trunks *III* and *IV* supplying area *I*. By means of diffusion their conduction will be interrupted, causing the so-called conduction anesthesia in this area. With the use of very weak solutions the nerve must be injected directly, diffusion under these circumstances being insufficient to interrupt conduction. Results of diffusion require waiting a certain time for anesthetic action.

If an anesthetic substance be injected into an artery or vein the circulation in which has been interrupted, terminal and conduction anesthesia will occur in the area of distribution of the respective vessels (arterial and venous anesthesia).

CHAPTER VII.

LOCAL ANESTHETIC AGENTS.

Local anesthesia received its greatest impetus following the discovery of substances of specific activity. From ancient literature we learn of the attempts which were made to produce local anesthesia by various drugs, which remained, however, without results until appropriate agents were discovered. The oldest of these, and for years the only local anesthetic, was the alkaloid cocaine derived from the coca plant. Its properties have been carefully studied, and inasmuch as these are typical of all local anesthetics, we will devote more time to it than to its substitutes, even though these have detracted in great measure from the parent drug.

COCAINE.

The coca plant (Erythroxylon coca Lam.) is indigenous to Peru and Bolivia, has been cultivated since prehistoric times, and been prominent in the religious and political life of the people. This plant was regarded as a gift of God which "satiated the hungry, gave renewed energy to the tired and weary, and caused the unfortunate to forget sorrows." (Novinny.) During the reign of the Incas only the royal families had the right to cultivate the coca plant and to enjoy its consumption. Francisco Pizarro, in 1532, while exploring the interior of Peru, found the coca leaves widely distributed and their use much abused. Under Spanish regime the cultivation of the coca plant was at first prohibited, later monopolized by the government, and finally the people again were accorded the privilege of cultivating the plant, which was, however, subject to taxation. According to Wedell, in Bolivia alone, in 1850, three million Spanish dollars were collected as a revenue from this plant. The interest of the scientific world was first aroused by the reports of travellers, as Tschudi and Poeppig, according to whom the coca leaves were chewed by the natives of South America in order to alleviate hunger, to produce wakefulness, and increase their physical powers of endurance. The continued and excessive use of the coca leaves ultimately resulted in a shattered nervous system. The natives still feel the necessity of the coca leaf when undertaking work which requires great physical effort. The green leaves when mature are picked, dried in the sun, and immediately packed. Scherzer was the first to bring a large quantity of these leaves to Europe; later Woehler, of Göttingen, received some of these leaves and from them his pupils, Niemann and Lossen, extracted cocaine. Cocaine was later synthetically prepared by Merck, Skraup, Einhorn, Liebermann and Giesel.

Cocaine ($C_{17}H_{21}NO_4$) crystallizes in large four- to six-sided colorless prisms. It is sparingly soluble in water, but dissolves readily in alcohol, ether, and ethyl chloride. It has a bitter taste and is of alkaline reaction. It melts at 98° C., being decomposed and converted into ecgonin. It combines readily with the acids to form salts, of which the hydrochloride is the best known and most frequently used therapeutically. Cocaine hydrochloride ($C_{17}H_{21}NO_4HCl$) is a white crystalline powder, readily soluble in water and alcohol, and when placed upon the tongue has a bitter taste. For the sake of brevity the term cocaine will be used to denote cocaine hydrochloride in the following paragraphs.

History of Cocaine Anesthesia and Cocaine Poisoning.—The discovery of the local anesthetic properties of cocaine gave a new impetus to local anesthesia, its history for more than twenty years being practically identical with that of cocaine anesthesia. Substitutes for cocaine have only been known in late years. The first reports regarding the anesthetic properties of cocaine were made by Scherzer, who noticed that the chewing of coca leaves caused a feeling of numbness in the tongue. The same properties were observed from the use of erythroxylin prepared from coca leaves by Garnicke (1855) and Percy (1857), and in a more pronounced manner from cocaine itself. (Niemann 1860, Demarle, Schroff 1862, Moreno y Maiz 1868, von Anrep 1879.) Von Anrep investigated the local action of this new remedy upon the skin and conjunctiva. He injected a weak solution of cocaine under the skin of his arm. There was at first a feeling of warmth, then loss of sensation to the prick of a needle at the point of injection. In about fifteen minutes the skin injected became red, which, after the lapse of twenty-five to thirty minutes, disappeared together with the previously mentioned symptoms. Upon instilling a solution of cocaine into the conjunctival sac of animals, he noticed only the previously well-known mydriatic action of the drug. On the other hand, Coupard and Borderau, in 1880, made positive observations as to the loss of corneal reflex in animals following the use of solutions of cocaine. Fauvel, Saglia, and others had already learned to use coca leaves and their extracts in the treatment of painful affections of the larynx and pharynx. This was the situation when Koller, and shortly thereafter Koenigstein, demonstrated that by the instillation of a 2 per cent cocaine solution the eye could be made sufficiently insensitive to permit the carrying out of all possible operations without pain. Koller's observations on this subject reported at the Ophthalmological Congress held in Heidelberg in 1884, were soon affirmed by Agnew, Moore, Minor, Knapp, Hirschberg, Graefe, Abadie, Panas, Trousseau and Horner, and cocainization of the eye and especially mucous membranes for the production of operative anesthesia was widely practised. In the same year cocaine was extensively used in laryngology (Jellinek, Schroetter, Stoerk, Zaufel, Fauvel) and rhinology (Bosworth, Lublinski). Otis and Knapp used this method of anesthesia upon the mucous membrane of the male urethra, while Fraenkel carried out similar experiments upon the female genitalia. This new discovery was of great value to ophthalmology, as many eye operations could be

more exactly performed than with general anesthesia. It was of like importance in laryngology and rhinology, where operations previously impossible could now be carried out. Schroetter, who at first was skeptical regarding the experiences of his pupil, Jellinek, shortly thereafter made the following statement: "One may now say that the technical difficulties of operating upon the larynx have been overcome and that laryngeal surgery can now be generally practised by all physicians." The present perfection of technic in laryngology and rhinology is inconceivable without an agent like cocaine which not alone allays pain and inhibits reflexes, but likewise causes a contraction of the mucous membrane, so that the larynx and nasal cavities become easily accessible.

By means of injections of solutions of cocaine into the tissues, this form of anesthesia became applicable in surgery and dentistry. At first very concentrated solutions were used (2 to 20 per cent), a few drops of which injected into the subcutaneous connective tissue produced in a short time, by diffusion of this agent, anesthesia, not only of the overlying skin but also of the deeper fascia, a fact long recognized by Anrep. By means of a number of such injections made near one another, large areas could be anesthetized, a method formerly in use by Corning, Roberts, Landerer, Woelfler, Dujardin-Beaumetz, Verchére, Hall, Witzel and others. An observation of great importance was made by Corning, in 1885, who reported that by interrupting the circulation better anesthetic effects could be obtained by the use of dilute solutions (0.25 to 0.33 per cent), and without the danger of poisoning, than had formerly been obtained with more concentrated solutions where the circulation was not interrupted. For the purpose of interrupting the circulation in the extremities, he used the Esmarch bandage; for other parts he constructed clamps and wire rings covered with rubber which were pressed upon the skin. He placed special stress upon the necessity of injecting the cocaine solution before interrupting the circulation. By the aid of this method Roberts was able to perform a partial resection of the elbow (cocaine used 0.06), and later an osteotomy of the femur for genu valgum (cocaine used 0.19) without pain. He made the observation at this time that after the injection of cocaine beneath the periosteum the latter could be separated from the bone and the bone itself divided without pain. Conway used this same method in anesthetizing fractures for the purpose of reduction. Anesthesia of a hydrocele sac by means of cocaine injections was performed by Burdel, Thiéry, and others. In the year 1887, thanks to the efforts of Woelfler, a large number of reports were collected regarding operations carried out under cocaine anesthesia (Schustler, Fraenkel, Spitzer, Chiari, von Fillenbaum, Lustgarten, Frey, Hoffman, Fux, Hochstetter, Orloff, and others). Cocaine anesthesia was used in all branches of surgery and was not limited to minor operations. Amputations of the leg, tracheotomies, extirpation of large tumors, herniotomies, and abdominal operations of all sorts were attempted with more or less success. Many surgeons (Woelfler, Fraenkel, Orloff) emphasized the necessity of infiltrating thoroughly the entire area to be operated upon with the anesthetic solu-

tion rather than depend upon its diffusion if one desired to anesthetize the tissues with certainty. Roberts, in 1885, described his method of saturating the skin with cocaine solution; he made superficial injections in the proposed line of incision, followed this by a subsequent injection at the periphery of the anemic zone produced by the first injection, continuing thus until the entire operative field was made insensitive; the deeper parts were anesthetized in a similar manner. The systematic development of this method, which is known today as Schleich's infiltration anesthesia, was made by Reclus and Schleich. The properties of this new agent were utilized in many other ways in the field of surgery. The observation of Corning and Goldscheider, made on both animals and man, that the conductivity of nerve trunks could be interrupted by cocaine solutions, with the result that the area innervated by these nerves became anesthetic, was put to practical use by Halstead, in 1885, in the extraction of teeth. In this operation cocaine was not injected around the tooth to be extracted but into the trunk of the infraorbital nerve, the injection being made from within the mouth. Later by means of a similar method Kummer and Pernice were able to amputate fingers and toes (Oberst). A very important observation was made by Corning in 1885; he injected a 2 to 3 per cent cocaine solution between the spinous processes of the lower dorsal vertebræ and noted the occurrence of anesthesia in the lower extremities from the effect of this agent upon the cord. Only in recent years has this so-called anesthesia of the cord become of practical value. We can only briefly mention that in 1886 Wagner and Herzog used the cataphoric action of the galvanic current in attempts to make the unbroken skin anesthetic, it being well known that cocaine solutions alone could not penetrate this structure. Thus in a short time local anesthesia by means of cocaine solutions was attempted in all possible ways, but the enthusiasm attendant upon the efforts made to replace general anesthesia by local anesthesia was destined to suffer the disappointments consequent upon its unrestricted use.

The first objection against the general use of local anesthesia was given expression by Hoffman and Fraenkel. The association of unconsciousness with general anesthesia became so fixed in the minds of the people that it was not readily controverted, or, as Fraenkel stated, most people desire to pass unconsciously the serious crisis associated with every operation. The second and more serious objection at that time was the great danger associated with cocaine anesthesia. Attempts were made in vain to counteract these serious consequences by the use of remedies known to be of value for other poisons. Too little attention was paid to the determination of the maximum doses and to the warning of Corning, who stated: "A remedy which has such a strong chemical affinity for nerve substance must also affect the heart and central nervous system when introduced into the circulation in concentrated solution."

Mild, severe, and fatal cases of cocaine poisoning have been observed in great numbers following the use of this drug internally and subcutaneously, and by local applications to mucous membranes, but most

frequently, of course, when used for surgical purposes. A compilation of the published cases of cocaine poisoning was made by Falk and later by Weigand. These cases naturally represent but a small part of the entire number observed. These statistics were lacking in exactness, inasmuch as the strength of the solution used was not mentioned; nevertheless, if one may judge from the tendencies of the time, concentrated solutions were used. A distinction must be made between those cases in which cocaine is introduced directly into the body and entirely absorbed, as in the internal administration or injections into the tissues and those cases in which only a portion of the quantity used is absorbed, as in anesthetizing mucous and serous membranes. In the latter case the size of the absorbing surface to which the cocaine is applied is of great importance. Ophthalmologists who use cocaine very frequently seldom have cases of poisoning; among Weigand's 26 cases there was not 1 fatality. The cause of death in the case reported by Bottard (*La Normandie med.*, 1887, cited by Huber) following the instillation of a 2 per cent cocaine solution into the eye must be considered questionable. The reason why so few cases of poisoning occur in the hands of the ophthalmologists is easy to understand, as the strength of the solution is seldom more than 2 to 4 per cent and the extent of the mucous membrane treated is very small. In 17 cases of poisoning following the application of cocaine to the nasal mucosa Weigand reports no death; in 12 cases of poisoning following applications to the mouth and pharynx there were 2 deaths; in 11 cases of poisoning after applications to the larynx there was 1 death. Three deaths are noted following the application of cocaine to the rectal mucous membrane, 2 of which no doubt refer to one and the same patient whose death caused the unfortunate surgeon, Kolomnin, to commit suicide. The use of cocaine solutions of from 2 to 10 per cent is particularly dangerous in closed cavities lined with mucous or serous membranes, such as the urethra, bladder, and scrotal cavity. In the 24 cases collected by Weigand there were many very severe cases of poisoning, with 3 deaths (Sims, 0.8 cocaine, concentration not given; Reclus, 1.0 cocaine in 5 per cent solution; Pfiter, 1.0 cocaine in 20 per cent solution). In a later case reported by Czerny, death followed an injection of 7 cc of a 1 per cent cocaine solution into the urethra. Two similar but unpublished cases were reported to the author personally where death followed the injection of several cubic centimeters of a 5 per cent cocaine solution into the bladder. Berger reports a case in which exitus lethalis followed the injection of about 0.35 cocaine in 2 per cent solution into the scrotal sac. A similar death occurred in 1905 after Brouardel injected 40 cc of a 5 per cent solution of cocaine into the scrotal sac, although the solution was allowed to drain out after three to four minutes. The number of deaths which actually occurred in this manner is certainly greater than the number reported, for which reason we must conclude that the application of strong cocaine solutions to large absorbent surfaces is dangerous and not to be recommended. Weigand reports 15 cases of cocaine poisoning with 4 deaths, the cocaine being administered by the mouth, the quantity varying from 0.8 to 1.5.

There have been 132 cases of poisoning reported following the hypodermic injection of cocaine with 8 deaths; this does not include the cases already reported by Berger. The strength of solutions used was 4 per cent or more, as near as could be determined, the total quantity being unusually large, as much as 4.0 having been given; in 2 cases, however, only 0.04 and 0.06 were given. The latter 2 cases Reclus and Auber do not regard as cases of cocaine poisoning. In the case reported by Bettelheim severe symptoms manifested themselves following the injection of 0.01 of cocaine in the forearm, the etiological explanation of which appeared doubtful to Woelfler. It is immaterial how one views these cases; nevertheless the fact is that Weigand's records show no less than 40 cases in which usually harmless doses of 0.01 to 0.05 in 5 to 30 per cent solution were injected, causing symptoms of poisoning, in some cases very severe. On the other hand, occasionally after the injection of a large dose (2.0 to 2.5, Buebler), only relatively slight symptoms of poisoning were observed. We can conclude from these observations that, although the quantity of cocaine injected may be accurately measured, there are many circumstances to be considered in the causation of poisoning other than the dosage. There may be a peculiarity in the constitution of the individual, an idiosyncrasy toward cocaine, or it may be that the cocaine itself is not of uniform action in all cases. Which one of these views is correct? Can cocaine poisoning be prevented, and how?

Physiological Action of Cocaine.—The physiological action of cocaine is that of a protoplasmic poison, affecting protoplasm whenever it comes in contact with it. The symptoms, therefore, manifest themselves at the place where the cocaine enters the body and also at distant points, on account of which we distinguish between a local and a general poisoning.

Character and Mechanism of Local Cocaine Poisoning.—Cocaine paralyzes temporarily and without permanent damage to the tissues, the function of sensory and motor peripheral nerves (Alms, Mosso), the striped and smooth muscle fibers (Albertoni, Sighicelli), and the heart muscle (Mosso), provided the solution is not too dilute when brought into contact with these structures. When cocaine solutions are applied to freely exposed nerve trunks, first the sensory and later the motor fibers lose their power of conduction (Torsellini, Feinberg, Alms, Kochs, Witzel, Goldscheider, Corning, Mosso). Herrenheiser showed that cocaine applied in this way can paralyze the optic nerve, while Aducco and Mosso (1890) demonstrated that a few drops of a 10 to 20 per cent cocaine solution placed on the floor of the fourth ventricle of the brain promptly paralyzes the respiratory center, but the animals could be kept alive by artificial respiration. The symptoms of general cocaine poisoning in men and animals show how particularly sensitive the central nervous system is to this drug. Albertoni found that cocaine, applied locally, inhibited the secretion of glands, the movements of spermatozoa, ciliated epithelium, blood corpuscles of the cray fish, lepidoptera larvæ, and amœbæ. The same author and Maurel noticed that solutions of cocaine in the blood paralyzed the leukocytes. The latter lost their contractility and power to penetrate the vessel walls, and became round and collected in capillaries. Danilewski, by the

application of cocaine to the feelers cut from the sea anemone, was able to see and study all the elementary symptoms of cocaine poisoning, which promptly disappeared upon the removal of the cause. Charpentier, Mosso, and others, showed that plants are similarly affected by cocaine.

The local application of cocaine causes contraction of the small capillaries and arteries, especially of the mucous membranes, so that locally the blood content of the tissues is temporarily diminished. Eversbusch, Laborde, and others regarded this oligemia as the basis of local and general cocaine poisoning. Maurel, after the most painstaking efforts, endeavored to prove that the paralyzed leukocytes obstructed the contracted capillaries, thus causing a disturbance of function of the protoplasm of the tissues. It was known long before these observations of Maurel that the action of cocaine was independent of the blood contents of the organs. As proof of these facts it might be mentioned that cold-blooded animals which can live for some time without blood, and organisms which have no circulatory system, react constantly to cocaine. If the blood of frogs is replaced by a solution of sodium chloride they will show the same symptoms of local and general cocaine poisoning as normal frogs or other warm-blooded animals. Excised organs (nerve-muscle preparation) of warm-blooded animals, while still in a living state, do not react differently to cocaine than those in the living animal. Arloing cocainized the eye of a rabbit and then cut the sympathetic of the same side; although the conjunctiva immediately became markedly hyperemic, the anesthesia persisted. It might be mentioned in this connection that the newer local anesthetics in part act similarly to cocaine, except that they do not cause contraction of the bloodvessels. Oligemia and even complete ischemia of the tissues are not able to produce many of the symptoms of cocaine poisoning, particularly the rapid onset of local paralysis of pain sense. (See page 36.) The influence of the anemia of the tissues can come into consideration only indirectly by the diminished blood supply retarding the absorption of the cocaine, thereby permitting it to produce a more intense local effect.

A direct effect of anemia on the symptomatology of cocaine poisoning can only be considered when organs easily affected by variations in their blood-content or pressure like the brain cortex are concerned. We will consider this subject again in another chapter.

The paralysis of leukocytes, contraction of bloodvessels, and anemia are not the cause but the consequence or the effect of cocaine poisoning, and are best explained as due to a chemical affinity of cocaine for the protoplasm. The nature of the chemical combination of the protoplasm with cocaine is not known; it can be assumed, however, that it must be a very loose one, which can be broken up as readily as it occurs, permitting the function of the affected tissues to return to the normal. The disintegration of these combinations is intimately associated with the vital forces of the tissues, since the symptoms of local cocaine poisoning can, under certain conditions, be continued indefinitely by interrupting the circulation of the part. From certain peculiarities of cocaine poisoning it is probable that cocaine which has once entered into chemical combination is not

taken up by the circulation as such but is split into its component molecules. This is in accord with the fact that in the excreta and organs of animals poisoned by cocaine, little or no cocaine can be found. According to Weichowski's investigations, a dog eliminates 5.1 per cent, a rabbit no part of a toxic dose of cocaine; on the other hand from the organs of recently killed animals treated with cocaine solutions the larger part (80 per cent) may be recovered. The disintegration of the alkaloids must have some association with the vital processes. The older experiments of Helmsing (1886) are not very valuable, since at that time there was no known chemical reaction for cocaine, still, the author conjectured that the cocaine was disintegrated within the body of the animal.

Various forms of protoplasm, different organisms, or parts of organisms are not equally susceptible to cocaine, one variety of protoplasm requires a larger dose than another before showing evidence of poisoning. The extent of cocaine poisoning is quite variable; at times the stage of excitation preceding every cocaine paralysis is very slight or not at all noticeable; at other times the paralysis is preceded by the most severe irritation. Very slight degrees of poisoning evidence themselves merely by excitation and functional stimulation, which symptoms produced by the use of coca leaves gave the latter historical prominence. The cerebral cortex is more sensitive to the action of cocaine than the medulla oblongata, and cord, therefore the principal symptoms of general cocaine intoxication in warm-blooded animals are due to a disturbance of function in these organs, giving rise to such symptoms as intense excitement, convulsions and paralysis.

The peripheral sensory nerves are likewise very sensitive toward cocaine, whether it reaches them by absorption, from a mucous membrane, from injection directly into the tissues, or by means of the blood supply (Alms, Maurel). The sensitiveness of the sensory end-organs of the human skin can be definitely determined by means of the skin wheal. The addition of 0.005 per cent (1 to 20,000) of cocaine to an indifferent solution, such as 0.9 per cent salt solution when injected into the skin, is sufficient to obliterate the sense of pain for a short time in the area injected (Braun, Heinze).

More dilute solutions show no such effect. Dilute and osmotically indifferent solutions of cocaine are painless when injected; concentrated solutions of 3 to 4 per cent cause sudden sharp pain, to be immediately followed by complete local paralysis. The duration of anesthesia varies with location and individual susceptibility, and increases with the strength of the solution. If the anesthetic wheal produced by the injection of a 1 per cent solution lasts twenty-five minutes, the injection of a 0.1 per cent solution in the same person and the same place will last only fifteen minutes. The freezing-point of various cocaine solutions is as follows:

0.1 per cent solution, freezing-point	0.020°
1.0 per cent solution, freezing-point	0.115°
2.0 per cent solution, freezing-point	0.23 °
3.0 per cent solution, freezing-point	0.305°
4.0 per cent solution, freezing-point	0.410°
5.8 per cent solution, freezing-point	0.565°

It will be seen that the physiological concentration is about 5.8 per cent. Weaker solutions than this (as low as 0.05 per cent) cause cellular swelling and pain upon injection, the latter often being obscured by the rapidly following paralysis. Watery solutions of 0.01 per cent cause severe pain upon injection. Injury to the tissues is not noticed after the use of weak, osmotically indifferent cocaine solutions. The swelling rapidly disappears without leaving any infiltration or other local changes. The intensity and extent of anesthesia produced by diffusion of the solution depends upon its concentration; the anesthesia following the use of weak solutions is limited to the area injected. Following the injection of 2 per cent cocaine solutions a relatively large anesthetic and hemianesthetic area surrounds the place of injection. If a 0.1 per cent solution of cocaine is injected into the subcutaneous connective tissue the overlying skin, as a rule, will not show any pronounced change of sensation; but if the strength of the solution is increased to 2 per cent or more, not only does the skin become anesthetic but also the deeper parts, such as fascia, muscle, periosteum, etc. In like manner, cocaine solutions will interrupt the conductivity of nerve trunks if injected into their immediate neighborhood in sufficiently concentrated solution (2 to 4 per cent). We will again refer to the history, theory, and practical application of this method. In regard to increasing the local effect of cocaine by preventing its absorption, see Chapter VIII.

Goldscheider found upon studying the relation of cocaine to the various sensations of the skin that the temperature sense and sensation of tickling were most susceptible to its action. He likewise made the remarkable observation that although the skin or mucous membrane of the tongue was anesthetized and the temperature sense completely obliterated, nevertheless hyperalgesia to irritation from heat was present. To be more definite, he found that where moderate warmth applied to the normal skin produced only a feeling of difference in temperature, in the cocainized skin or mucous membrane it produced severe pain. From this it may be concluded that a condition of irritability of the pain sense nerves exists. The correctness of these observations of Goldscheider has been verified.

Touch and pressure sense are less sensitive to the action of cocaine than the pain sense, it being frequently observed that after the local application of cocaine, although analgesia is present, touch and pressure sense are not disturbed. After the application of cocaine in a solution of sufficient strength to produce complete anesthesia, touch and pressure sense return first, then pain sense, and lastly the temperature sense. These observations do not agree with those of Goldscheider.

This experiment can best be carried out by injecting into the cutis 0.001 to 0.1 per cent cocaine solution in 0.9 per cent salt solution. A considerable area will thus be anesthetized, the degree of anesthesia depending upon the concentration of the solution. In this area the reaction of the senses to irritation can be accurately tested. The quantity of cocaine used is so small that any symptoms of a general nature can be excluded, although Mosso (1890) noticed an increasing hyperesthesia of the entire skin after

the internal administration of 0.05 to 0.1 cocaine in man. It can also be determined that the duration of anesthesia increases with the concentration of the solution. It can be further shown that the weakest solutions (0.001 to 0.003 per cent), the concentration varying with the time and individual, cause a loss of temperature sense only and a hyperalgesia toward irritation from heat. Slightly stronger solutions (0.005 per cent) cause analgesia, and still stronger solutions cause a loss of all sensation. If the course of the anesthesia is now tested, it will be constantly noted that touch and pressure sense return first, pain sense next, and last the temperature sense. It will also be noticed during the disappearance of the anesthesia, when cutting, pricking the skin, and faradic irritations are scarcely recognized as pain, that hyperalgesia to the irritation of heat is present. This observation is of considerable practical significance in surgery and offers an explanation of the fact that the use of the thermocautery on tissues anesthetized with cocaine causes a rapid return of pain sense. We now have no further need for the improbable theory of Reclus, that the effect of the heat of the thermocautery caused a more rapid destruction of the cocaine present in the tissues. In a finger which has been rendered completely anesthetic by the injection of the nerve trunks with a solution of cocaine, the order in which the various skin senses return can be observed readily as the local effect of the cocaine gradually disappears.

Cocaine applied to mucous membranes paralyzes not only the pain sense but also the other inherent senses such as taste and smell (Zwaardemacker).

The motor nerves are so much less sensitive to cocaine than the sensory nerves that it has been held that they are immune, but Alms and Kochs, later Mosso (1890), Laewen, and Gros demonstrated that this was not the case. Mosso, following the application of cocaine to the nerves of the diaphragm of a dog, observed a rapidly ensuing paralysis of this structure. Frank utilized this property of cocaine in his physiological experiments on living animals in place of cutting the nerves. Alms and Maurel injected cocaine into an artery of an animal and noted a motor paralysis in the area supplied by it. Mosso replaced the blood in the vessels of the extremities of frogs and warm-blooded animals with salt solutions and defibrinated blood containing cocaine in various quantities. If the solution contained 0.6 per cent of cocaine the muscles were first stimulated, then paralyzed, returning to normal when the vessels were flushed with salt solution or blood. If the above solutions contained larger quantities of cocaine, paralysis ensued immediately. In experiments on conduction anesthesia in man, an interruption of conductivity of both motor and vasomotor tracts of mixed nerves occurred when the action of the cocaine was sufficiently intense; the sensory tracts were, however, more quickly paralyzed and the anesthesia was of longer duration than the motor paralysis. If the action of the cocaine was less intense, motor paralysis did not occur, whereas sensory paralysis was complete.

According to Mosso the frog's heart becomes stimulated when salt

solution containing 0.04 per cent cocaine is passed through it, and paralyzed when 0.08 per cent of cocaine is contained in the solution, the heart returning to normal if not further addition of this substance is made. Albertoni was able to paralyze the larvæ of lepidoptera and amœbæ when placed in 0.5 per cent cocaine solution. In regard to the sensitiveness of plants, it has been found that 0.05 to 0.1 per cent cocaine solutions accelerate the germination of the seed and the growth of the plant, 1 per cent solutions hinder these processes, while 2 per cent solutions cause a complete interference with growth and development. The leukocytes are particularly sensitive to cocaine; Maurel states that the leukocytes are paralyzed by the addition of 0.02 per cent cocaine to the human blood. The collection of immobile leukocytes in the capillaries constantly occurs in general cocaine poisoning, but has not the significance ascribed to them by Maurel. Since the sensory nerves have been shown to be most sensitive to cocaine, it is only natural to ascribe to cocaine a certain specific action upon the peripheral sensory nerves. Until the discovery of cocaine there was no known substance which was able to exert a decided action upon the peripheral sensory nerves without marked irritation or permanent damage to them.

The term "sensitive curare," which was applied to cocaine by Anrep, Laffonte, Laborde, and Dastre, is certainly not applicable, as the motor and sensory paralysis following the ingestion of toxic doses of cocaine are central in nature, and are not due to the action of this agent upon the peripheral nerves (Mosso).

Character and Mechanism of General Cocaine Poisoning.—Cocaine introduced into the body and absorbed into the circulation may act upon the protoplasm of organs in places remote from the point of introduction. These organs will respond to the toxic agent with irritation or paralysis if the blood passing through them contains cocaine in sufficient quantity to affect them. This rule formulated by Albertoni is the key to the understanding of the peculiar manifestations of local or general cocaine poisoning.

The historically important property of small doses of cocaine was studied by Mantegazza among the natives who chewed the coca leaf. He observed that motion and sensation were temporarily stimulated within normal limits; perception and transmission of nerve impulses, as well as metabolism, were increased. This was later observed by Anrep, Mosso, Fleischer, Freud, and others to apply to the use of pure cocaine. This undoubted central action of small doses of cocaine is of little importance in the consideration of our subject. To better understand the rapidly changing picture of acute cocaine poisoning following the introduction into the body of large doses of this poison, we will follow the description of Husemann. In studying the symptomatology of this condition we find the chief disturbance in the organs most sensitive to cocaine, namely, the central nervous system. In the mildest form of poisoning there is a sudden but usually transient attack of vertigo quickly following the application of the cocaine. This attack may, however, become more severe and be followed by fainting, small compressible pulse, formication, cold extremities,

irregular, difficult respiration and cold sweat. In more severe cases these symptoms are accompanied by unconsciousness, and followed by symptoms of general weakness lasting several hours. Vomiting is frequently associated with this condition. As previously mentioned, it is possible, or rather probable, that the cerebral anemia present in the milder forms of cocaine poisoning has a certain but unimportant part. A condition indicating a greater degree of poisoning is characterized by more or less excitation of the cerebral cortex (cocainerausch). The patients are unnaturally excited; they are usually in good spirits, laugh, chatter, have hallucinations and very frequently melancholia and ideas of persecution. Various abnormal subjective sensations occur, such as dryness of the throat, precordial distress, paresthesia, anesthesia, loss of sight, smell, and hearing. The pupils are dilated and fixed as after the local instillations of cocaine into the eye; the excitation may develop into mania. Severe, dangerous cocaine poisoning almost always begins with severe epileptiform convulsions with exophthalmos and unconsciousness, followed by loss of sensation, motion, reflexes, and lastly the corneal reflex. The patients are in deep coma and death ensues in consequence of paralysis of the respiratory center. A succession of the phenomena of cocaine poisoning is similar to that of the inhalation anesthetics, such as chloroform, ether, etc., except that in the latter the symptoms of irritation are slight, those of paralysis predominating, while in the former the symptoms of irritation of the central nervous system are most prominent. Individuals having a tendency to convulsions develop these symptoms much more readily than others after the use of cocaine. It has been noticed in nervous individuals that convulsions have occasionally occurred three to four weeks after the poisoning. The manifold symptoms of acute cocaine poisoning have not been exhausted with this description, as there is hardly a pathological symptom of the body which has not been observed in this condition. Experimental investigations regarding general cocaine poisoning in animals have been made by von Schroff (1862), Danin (1873), von Anrep (1879), Volpian (1883), Mosso, (1887), Albertoni (1890), Maurel (1892), and many others, and the association of the phenomena explained. As in man the symptoms are confined almost entirely to the central nervous system. In intelligent animals, as dogs, after the use of small doses of cocaine a similar irritation of the psychic centers is observed the same as in man, excitation, depression, and hallucinations (Feinberg, Blumenthal, and Mosso). Every severe case of poisoning in warm-blooded animals begins immediately after the administration of cocaine, with severe clonic convulsions, exophthalmos, and loss of consciousness. In cold-blooded animals convulsions are absent. In warm-blooded animals they may be absent or almost so, if the poison is administered gradually in dilute solutions. As is observed in man, the convulsions are succeeded by coma, with loss of consciousness, motion, and the reflexes, death ensuing during or after the stage of convulsion from paralysis of respiration. Feinberg and Blumenthal have demonstrated the central origin of cocaine convulsions, the symptoms not occurring in animals in which the cortical

motor centers have been extirpated. These symptoms are likewise absent in newborn animals in which the cortical centers, according to Soltmann, cannot be stimulated before the twentieth day. Finally, these symptoms do not occur if the cerebral cortex has been previously paralyzed with chloroform, ether or chloral hydrate (Mosso). The observations of Feinberg and Blumenthal, which were later verified by Soulier and Guinard, seemed to point to cerebral anemia as the cause of the convulsions. There can be no further doubt at present that the specific effect of the poison on the central nervous system is the cause of the stimulation of the cortex. In the first place, the brain is not anemic during the stage of convulsions, but, to the contrary, enormously overfilled with blood, for which reason we notice the condition of exophthalmos, and, secondly, drugs closely related to cocaine in their action, but which do not cause cerebral anemia, give rise to similar convulsions (tropacocaine). Sensory and motor paralyses caused by cocaine are purely of central origin, as shown by Mosso, for even in the deepest coma, muscles and peripheral nerves retain their power of reacting to stimuli, while on the other hand paralysis of an extremity does not occur when excluded from the circulation of the poisoned animal. Recent investigations (Kast and Meltzer, Ritter, A. W. Meyer) seem to show that the peripheral nerve endings likewise can be indirectly paralyzed by the introduction of sufficient cocaine intravenously.

During the experiments on animals poisoned by cocaine many peculiarities of the effect of this drug should be noted which find their explanation in the action of this alkaloid upon the protoplasm. We have learned that the chief properties of cocaine are: (1) Its marked affinity for living protoplasm of all kinds, which causes its fixation as soon as the substance is introduced into the body. (2) Its ability to enter into less stable compounds with the protoplasm whose functions are temporarily interrupted and its rapid disintegration, as a result of which it does not enter the circulation again as cocaine. These properties form the basis of the local anesthetic qualities of the drug and explain the following peculiarities of cocaine poisoning:

If cocaine solutions be injected intravenously into animals, they react promptly and uniformly to definite doses of cocaine, provided the doses are dissolved in the same quantity of water or other solvents. The same dose will act differently, however, if of different concentration, or if instead of being administered as one dose is injected at short intervals. This reaction of cocaine was first studied by Maurel.

According to the experiments of Maurel, if 0.01 cocaine in 5 per cent solution be injected into a vein in the ear of a rabbit, death immediately follows; 0.005 per kilo causes violent convulsions; 0.0025 causes mild symptoms of poisoning. If 0.002 per kilo in 5 per cent solution be repeatedly injected intravenously at intervals of five to ten minutes, 0.03 per kilo of cocaine can be given without the occurrence of poisoning. Poisoning will likewise not occur if 0.03 per kilo of cocaine be injected in 0.25 per cent instead of a 5 per cent solution. Similar experiments by

the author were reported by Weigand as follows: Three rabbits of approximately the same weight (1800 gm.) were injected in a vein in the ear with cocaine, the first, 0.005 in 10 per cent solution; result: severe convulsions and paralysis; the second, 0.005 in 1 per cent solution; result: no poisoning; the second 0.01 in 1 per cent solution; result: short, violent convulsions; the third, 0.02 in 0.2 per cent solution; result: transient weakness; the third, 0.02 in 0.1 per cent solution; result: no poisoning.

It will be noted from the above that four times the quantity of cocaine will be borne by an animal in 0.1 per cent solution without injury, which in a 10 per cent solution causes very severe symptoms on the part of the central nervous system. The weakening of the toxic effect of a quantity of cocaine injected intravenously in divided doses was observed by Feinberg and Blumenthal in their experiments on dogs. The explanation of these facts is determined by the properties of cocaine. The latter, introduced into the blood, irritates and paralyzes the susceptible nervous system, before the other organs have had an opportunity to react, although they were equally exposed to its toxic action. Cocaine poisoning of the central nervous system, that is, the picture of general cocaine poisoning, occurs when the blood passing through the central nervous system contains the alkaloid in a sufficiently active concentration for this organ, even if the contact with it be but momentary. If this concentration be less, repeated doses of cocaine may be administered for a time, as the small quantities contained in the blood become immediately combined and ultimately disintegrated. Acute poisoning will therefore not occur, as the living cells of the central nervous system can withstand and render harmless the small doses they receive as long as the cocaine and its disintegration maintain a definite balance. These conditions are very similar to those resulting from the inhalation of ether and chloroform. These substances do not possess a maximum dose. A small quantity of either of them can cause a paralysis of the centers in the medulla oblongata with instant death of the patient, if contained in the blood in concentrated form. Many hundred times this quantity can be gradually administered, as the degree of poisoning from either chloroform or ether depends entirely upon the quantity of their vapor in the respired air of the individual. The occurrence and intensity of cocaine poisoning are not alone dependent upon the quantity given, but also upon the time during which it is administered. If introduced into the blood suddenly, that is, in concentrated solution, death may occur immediately, while if gradually introduced, that is, in dilute solution or if given in divided doses, poisoning will not manifest itself, as the concentration of cocaine in the capillaries of the central nervous system is never of sufficient concentration to be toxic to this organ. The toxic effect of concentrated and dilute solutions is not so marked with other substances as it is with cocaine. Poisons which at their point of application produce stable changes and accumulate do not show the phenomena to such a marked degree, as they must be administered gradually in repeated doses, in consequence of their cumulative action. This finally brings about the same condition as when a like dose is rapidly

absorbed. We shall later study the action of the drug "akoin," a local anesthetic which belongs to this class of poisons.

Animals can withstand much larger quantities of cocaine solution injected into the subcutaneous connective tissue, or between the muscles, than when the same quantity and of like concentration in injected into the veins, leaving out of consideration temporarily some of the irregularities of action of this alkaloid. Custer observed that 0.03 per kilo in a 5 per cent solution was the smallest quantity that would show evidence of poisoning in rabbits, and that 0.1 per kilo was always a fatal dose. Experiments by the author show that 0.02 per kilo in a 10 per cent solution caused no symptoms, 0.03 per kilo was, as a rule, followed by poisoning, and exitus lethalis occurred regularly after the administration of 0.1 per kilo. Most authorities consider the dose of 0.1 per kilo fatal for rabbits. The dose which can be administered to rabbits subcutaneously with toxic or fatal effect is almost ten times as large as that which will produce like symptoms administered intravenously. The cause for this difference lies mainly in the delayed absorption of the alkaloid, part of which enters into a local combination with the tissues, the remainder reaching the central nervous system in more dilute form. However, in intravenous injections the full dose cannot reach the central nervous system, inasmuch as the paralyzed leukocytes fill the capiliaries and must necessarily absorb a portion of the poison. The affinity of cocaine for all tissues, and their power of reducing portions of the drug is best shown when the solutions are introduced subcutaneously. It will again be seen that the effectiveness of the dose administered subcutaneously is dependent in large measure upon the concentration of the solution. Ponchet injected two guinea-pigs of equal weight, one with 0.04 cocaine in 4 per cent solution, the other 0.1 in 0.66 per cent solution; the first died after a few seconds, the second was poisoned but did not die. Experiments on rabbits demonstrated that a 5 to 10 per cent solution containing 0.1 of cocaine per kilo was fatal, whereas the same quantity administered in a 1 per cent solution caused mild symptoms of poisoning or none at all. It was also shown that cocaine in dilute solutions did not produce convulsions to the same extent as the more concentrated ones. According to Maurel, 0.025 of cocaine in 0.1 per cent solution is fatal for rabbits, while experiments by Custer and others demonstrated that 0.1 per kilo in 0.1 per cent solution did not produce poisoning; the first toxic symptoms showed themselves only after the administration of 0.15 per kilo, and even after the administration of 0.3 per kilo death did not occur. The widely varying results of Maurel's experiments can be explained by the fact that he used large quantities of a watery solution of cocaine for subcutaneous injections. The animals did not die of cocaine poisoning, but, as Custer has shown, in consequence of the injection of water, which could have been prevented by the addition of salt to the solution.

Thus a quantity of cocaine injected subcutaneously in 5 to 10 per cent solution causes the same toxic symptoms as five times the quantity in 0.1 per cent to 0.2 per cent solution, the reasons for which have been

previously given. Maurel made most interesting observations following the injection of cocaine solutions into the arteries of rabbits instead of into their veins. He found that he could inject 0.1 per kilogram in 10 per cent solution into the femoral or renal artery without causing any evidence of poisoning, whereas the control animals died after injecting 0.02 per kilogram into their veins. Maurel's explanation of the action of cocaine is certainly incorrect, no matter how plausible it may seem. In 1900 the author injected into the femoral artery of a rabbit weighing 3000 gm. 0.1 cocaine corresponding to 0.033 per kilogram in 10 per cent solution with an immediately fatal result. In the case of a second animal the injection of 0.01 per kilogram in 10 per cent solution into the femoral artery caused severe symptoms of poisoning, but the animal did not die. It is very necessary in these experiments to be sure that the arterial circulation is not in any way interfered with during and after the injection, so that the cocaine as intended, can immediately enter the circulation.

Mosso noticed that dogs sometimes respond differently than usual to concentrated cocaine solutions injected subcutaneously. One dog failed to be poisoned by 0.02 to 0.03 per kilo, while another one died quickly after the same dose (0.03). Anyone who has made such experiments must have come to the conclusion that we cannot without some reserve speak of a fatal, toxic or non-toxic dose when using cocaine in this manner. In experiments on animals the same uncertain action of cocaine is encountered as has been noted in the history of cocaine anesthesia in man, causing the widespread belief in an idiosyncrasy toward this drug. It is certain that there are persons more susceptible to the action of cocaine than others, but in the large majority of cases poisoning following the injection of small doses of cocaine must be explained otherwise than by an idiosyncrasy. The difficulty of determining the proper dosage of cocaine is noted in animal experimentation as well as in the later observations in man. In animals the irregular action of cocaine such as the toxicity of relatively small doses or the harmlessness of correspondingly large ones, becomes evident when concentrated solutions are used subcutaneously. Intravenous injections of cocaine show a positive relation between the concentration of the solution and the symptoms following. It has been repeatedly demonstrated that the so-called idiosyncrasy in man disappears if instead of a concentrated a dilute solution of cocaine is used for injection. It has been shown that an animal will react differently to a certain dose of cocaine at different times. If 0.03 per kilo of cocaine in a 10 per cent solution is injected subcutaneously into a rabbit, severe symptoms of poisoning will usually occur, such as convulsions with consequent paralysis, without, however, causing its death. On June 19, 1898, a rabbit weighing 2850 gm. was injected under the skin of the back with 1 cc of a 10 per cent cocaine solution (0.035 per kilogram) without being poisoned. This animal reacted in like manner several days before to 0.03 per kilogram, and did so again three days later. This speaks against Aducco's theory of a cumulative action of the drug, and also against a tolerance of the drug as suggested by Custer. Similar observations have been frequently

made on human beings, principally following the anesthetizing of mucous membranes where exact dosage was impossible. Weinreich reports a severe case of poisoning following an injection into the bladder of 2.0 cocaine in 20 cc of water, although five times this quantity had previously been borne by the patient; seven days later 1.0 cocaine in 30 cc of water was used in the same manner without poisoning. This same author reports a second case which reacted in the same manner. Bergmann reports a case in which severe cocaine poisoning followed the injection into the thigh of 0.02 in a 5 per cent solution, although 0.05 in 5 per cent solution had been well tolerated the day before. Hobbs and Rieke make similar reports regarding the anesthetizing of nasal mucous membranes, and Hobbs is therefore of the opinion that we cannot speak of a toxic or of a non-toxic cocaine dose, since the same persons will react differently to like doses of cocaine at different times. On the other hand, very few cases have been reported in which there is a permanent hypersusceptibility to cocaine. It is not at all necessary in order to explain all these phenomena to assume an idiosyncrasy toward the drug. The typical and regular action of cocaine is noticed only after intravenous injections. Extremely small quantities of a concentrated solution are sufficient to severely injure the central nervous system. The more dilute the solutions used in this manner the larger the dose necessary to produce the same toxic symptoms.

Much larger doses of a concentrated cocaine solution can be applied to mucous membranes, and injected subcutaneously than can be injected intravenously, as its absorption is delayed, causing the cocaine reaching the central nervous system to become more dilute, thus preventing symptoms of poisoning. Should a small quantity of a concentrated solution find its way into a blood or lymph vessel or be very rapidly absorbed, owing to the nature of the part injected, then relatively small doses act as though injected intravenously. In this manner the affinity of cocaine for protoplasm can be explained, as well as its local anesthetic properties, which before the discovery of the drug was never observed in connection with any other substance. This also explains its general action, the difference in toxicity between concentrated and dilute solutions, and the apparent irregularity of like doses when injected intravenously and subcutaneously. In order to understand local and general cocaine poisoning it is necessary to always keep in mind the fact that general and local poisoning stand in definite relation to the rapidity of absorption.

The Prevention and Treatment of Cocaine Poisoning.—The Dosage of Cocaine.—How to avoid the dangers of cocaine can be learned from a study of the preceding observations and the following experiments on human beings. It is not sufficient to consider a certain dose as the absolute maximum, as the authorities differ widely upon what they consider a safe dose. The difficulties in this connection will be realized after a consideration of the doses recommended by the following authorities: Landerer, 0.01; Woelfler, 0.02 to 0.05; Kocher, 0.1; Reclus, 0.2; Gluck, 0.2 to 0.3. In the German pharmacopœia 0.05 is given as the maximum dose. These statements must be changed, as reliance upon them has recently resulted

in severe poisoning (Bergmann). The maximum dose of cocaine is not 0.05, as this dose neither protects one from cocaine poisoning nor represents at all times the largest dose that can be used with safety.

The largest quantity of cocaine which can be injected directly into the blood stream in concentrated form without producing symptoms of intoxication should be considered the maximum dose. This quantity will be found much smaller than that recommended by the German pharmacopœia and will be found to be a portion of a centigram. This fixed maximum dose is without the least practical value, for by the observance of certain precautionary measures much larger doses of cocaine can be introduced into the body without danger. These precautionary measures consist principally in preventing a too rapid absorption of the drug, so that the smallest maximum dose enters the blood stream at one time. Very large doses of cocaine can be used without toxic effect if introduced gradually into the body or if a too rapid absorption is prevented, whereas small doses if rapidly introduced into the circulation can give rise to symptoms of poisoning. The latter can be most readily avoided by using very dilute solutions for anesthesia, so that in the dilution of solutions of cocaine we have the secret of preventing poisoning.

The necessity of using very dilute solutions of cocaine for injection was suggested by Corning shortly after the introduction of this agent. He demonstrated that anesthesia could be produced by using 0.33 to 0.2 per cent solutions with the aid of the Esmarch bandage. Fraenkel likewise observed that larger areas could be anesthetized by a certain quantity of cocaine if 1 instead of 10 per cent solution was used. In the discussion of Berger's case of cocaine death, at the Paris Surgical Society (1891), Motty stated that he used 0.5 per cent cocaine solutions entirely without having one serious accident in thousands of cases in which it had been injected. Oberst (Pernice) since 1889 used principally 0.5 to 1 per cent solutions of cocaine and the author who studied his methods and has employed them almost daily has never observed a case of cocaine poisoning. We are indebted for the knowledge of these principles to the efforts of Reclus and Schleich. Reclus, in numerous original articles and those of his pupils (Auber, Fillon, Delbose, Legrand), expressed the opinion that cocaine poisoning was due, as a rule, to an idiosyncrasy and believed that it could be avoided by proper technic. He perfected a method whereby he could use a 1 per cent solution, later a 0.5 per cent solution, without the use of the Esmarch bandage, for performing major operations which were formerly only possible under general anesthesia. He reports over 7000 cases to prove the harmlessness of cocaine when used in this way. Ceci, Hackenbruch, and many others promulgated this teaching. Schleich later taught that with even more dilute (0.1 to 0.2 per cent) cocaine solutions and with the aid of a special technic and the use of cold the field for cocaine anesthesia could be materially extended. Solutions containing more than 0.5 to 1 per cent of cocaine should never be used for injection.

In what dosage can dilute solutions be used? The older literature

only deals with cocaine poisoning following the use of concentrated solutions, the maximum dose of which, according to the experience of Woelfler, should not exceed 0.05.

It has already been shown that this supposed maximum dose neither protects the patient from poisoning nor does it represent the quantity of cocaine which can be used without danger. The experience of Reclus with more than 7000 patients seems to indicate that if a 0.5 to 1 per cent cocaine solution is used, at least double the quantity above mentioned can be injected. He has used as much as 0.2, and beyond an occasional transient excitability has never experienced serious consequences since using the dilute 0.5 to 1 per cent solution. Reclus holds that certain measures of precaution are absolutely necessary. Cocainization should only be performed in the horizontal position, the patient to continue in this position two to three hours following major operations and twenty minutes after minor operations. The injection is never to be made with the needle stationary, but should be made during its insertion and withdrawal to avoid injecting a considerable quantity of cocaine into a vein. With the use of the still more dilute Schleich solution (0.1 to 0.2 per cent), 0.1 of cocaine can be used with less danger. An efficient method of retarding the absorption of cocaine and thus preventing after effects is, as was already pointed out by Corning in 1885, the interruption of the circulation by constricting the extremity. No serious cases of poisoning have been reported in which the extremities were ligated before injection, and if the advantage would warrant the use of concentrated solutions, there would be no serious consequences attending their use with this precaution. It is essential that the constricting band should be allowed to remain at least half an hour after the injection; or the method as recommended by Dumont, Wyeth, Barton, and Mattison can be used, in which the band is loosened several times for two or three minutes before entirely removing it, permitting in this way a gradual absorption of the cocaine remaining in the extremity. For more definite information concerning the artificial production of anemia and the prevention of the too rapid absorption of cocaine, see Chapter VIII. The same precautions must be observed in anesthetizing large absorbent surfaces, as when injecting the tissues, that is, the prevention of the rapid absorption of even small doses of cocaine. Anesthesia of the mucous membranes of the eye, nose, mouth and larynx can be rapidly induced by using a 20 per cent cocaine solution. We cannot speak of dosage under these conditions, but it is necessary to see that only small areas are anesthetized at one time, and that the surplus solution does not run into the mouth, nose, pharynx, and esophagus; in this way the danger of severe cocaine, poisoning can with reasonable certainty be avoided. To expose large absorbent surfaces, such as the mucous membrane of the bladder, urethra, scrotal sac, and joint cavities to the action of concentrated solutions of cocaine, is extremely dangerous, as has been noted in the history of cocaine anesthesia. This danger cannot be avoided, no matter what quantity of a solution is injected into a body cavity. The case of Berger has already been mentioned in which 0.35 of cocaine in 2

per cent solution was injected into the scrotal sac and immediately drained off again; nevertheless, death promptly followed. We cannot attribute this unfortunate experience to the dose of 0.35 cocaine any more than we can explain similar results following the injection of cocaine into the bladder and urethra. In the latter cases the bladder is emptied and washed out, and the fluid injected into the urethra runs out of its own accord. These accidents would no doubt have happened even if small quantities of the solutions used had been injected. It is to be assumed that as much cocaine will be absorbed from 5 cc of a 5 or 10 per cent solution allowed to act for a certain time on the bladder mucosa as will be absorbed from 10 cc of the same solution allowed to act for the same length of time. General or local conditions (ulcer of the bladder) can in some cases cause a more rapid absorption of cocaine with consequent symptoms of poisoning. The question, therefore, confronting us is not how large a dose of cocaine can be introduced into these cavities, but what is the maximum strength of the solution to be used. The answer to this question in reference to the body cavities, as the bladder, scrotal sac, and joint cavities, is to use 0.1 to 0.2 per cent solutions, and if sufficient time is allowed for the action of this solution, the resulting anesthesia will equal that induced by a 10 per cent solution. The urethra in the male can be anesthetized with a 1 per cent solution in a short time, but solutions of this strength should not be used for the other cavities of the body. With the beforementioned dilute solutions, however, cavities can be filled with any quantity desired, the absorption in twenty to thirty minutes being only a few milligrams of cocaine, the exact quantity being impossible of measurement, and consists only of that amount of cocaine which can diffuse through the wall of the cavity. It is immaterial if we inject 100, 200, 300 or more cubic centimeters of the solution containing cocaine in the dosage mentioned, as toxic symptoms may certainly be avoided.

It has been attempted, by the addition of various substances, to localize the action of cocaine. Stuver suggested the addition of antipyrin (5 cocaine, 10 antipyrin, 100 water), Gluck carbolic acid, and Parker resorcin. Many experiments have failed to prove that the addition of 4 per cent carbolic acid to watery solutions of cocaine lessens its toxicity or increases its local anesthetic properties. Gauthier, Thomas, and Guitton recommend the addition of nitroglycerin (10 drops of a 1 per cent solution of nitroglycerin to 10 cc of a 1 per cent cocaine solution), expecting by the dilating effect of nitroglycerin to counteract the contraction of the bloodvessels as produced by cocaine. Inasmuch as the contraction of vessels is only one symptom of cocaine poisoning this agent would, by its dilating effect on the vessels, be of value only in those cases associated with anemia of the brain. Instead of adding nitroglycerin regularly to cocaine solutions for its prophylactic action, it would seem that the use of amyl nitrite in cases of poisoning would be better, as this drug acts similarly to nitroglycerin, causing dilatation of the vessels of the head immediately upon being inhaled. What is better is the avoidance of anemia of the brain by keeping the patient in the horizontal position.

According to Woelfler toxic symptoms occur more readily following injections of the face and scalp than those of the trunk and extremities, for which reason he considers 0.02 as the maximum dose for injections of the head against 0.05 for the body. Animal experiments, as well as the collection of the published reports of cases of cocaine poisoning, give no information on this question. Reclus, with his large experience, never observed this difference when using more dilute solutions, and believes that the experience of Woelfler was due to the fact that many operations on the head were performed with the patient in the sitting posture.

If, as has been mentioned, an idiosyncrasy does not exist, and the irregular action of cocaine can be ascribed to peculiarities of the drug itself, it cannot be denied that the central nervous system reacts differently to nerve poisons in different individuals, and likewise in its reaction toward cocaine. With the presence of such an indefinite susceptibility we cannot formulate rules for the use of cocaine.

In cases in which the use of concentrated solutions of cocaine cannot be avoided, as in laryngology and rhinology, the bodily condition of the patient must be taken into consideration. Intoxication from cocaine seems to affect both sexes alike. According to Trzebicki, children are less tolerant than adults, while Felizet regards children as particularly sensitive toward cocaine. Great care must be exercised in administering cocaine to debilitated and nervous persons, those with serious heart lesions, patients weakened by the loss of blood or prolonged illness, alcoholics, and those suffering from hysteria and epilepsy (Lewin). However, with the cautious use of weak cocaine solutions this method of anesthesia is indicated in these conditions to avoid the use of general anesthesia. With the increase in knowledge of the action of cocaine this dangerous drug can be used very extensively in surgical operations without danger to the patient if the proper rules for its administration be observed. With the proper prophylaxis toxic symptoms on the part of the central nervous system seldom occur.

As there is no known antidote for cocaine our efforts must be directed to combating the symptoms of poisoning. The head is placed low and, according to the recommendation of Schilling, the patient is permitted to inhale a few drops of amyl nitrite, an agent which seems to be of decided benefit in the early stages of poisoning. By this means anemia of the brain can be prevented, permitting the central nervous system, owing to its richer blood supply, to more easily eliminate the cocaine. It is a matter of common observation that the local effects of cocaine disappear much more quickly in hyperemic than in anemic tissues.

Opiates are necessary for the control of convulsions. Observations by Mosso in animal experiments showed that convulsions do not occur if the animal has been benumbed with chloral hydrate, ether or chloroform. These drugs cannot be used in man without great caution, and opiates should only be given during the period of excitement. If the poisoning progresses to the point of causing paralysis of the central nervous system, narcotic drugs are no longer antagonistic but act in the same

manner as the poison which they are intended to control. It is, therefore, advisable to use a rapidly acting substance such as ether inhalations for the control of the convulsions, but its administration must be stopped as soon as it has accomplished its purpose. In severe cases of cocaine poisoning it is most important to stimulate the action of the heart by rubbing the skin, by the administration of stimulants by mouth or subcutaneously, and in case of threatened paralysis of the respiratory center, artificial respiration must be immediately instituted.

Legrand reports a case in which a patient was injected subcutaneously with 1 per cent cocaine and kept alive by artificial respiration continued for five consecutive hours. In poisoning by mouth the stomach must, of course, be washed out. In acute poisoning following injection into an extremity, the latter must be immediately ligated by a rubber tube or band which is kept in place for about an hour; in case the injections are made into other parts of the body, attempts must be made to delay absorption by cooling the part either with the ether spray or the application of an ice-bag.

Local Injury to the Tissues from Cocaine Solutions; the Preparation and Sterilization of Cocaine Solutions.—Reports of local damage to the tissues from subcutaneous or submucous injections of cocaine solutions are found only in the older literature. Local gangrene has been observed several times at and around the point of injection, and local edema has been frequently observed (Strauss, Bousquet, Johnson). These conditions are usually ascribed to the use of unclean preparations, the presence of moulds, and insufficient sterilization of the solution or operative field. It has also been observed that very concentrated solutions irritate the tissues, and by their dehydrating action injure the tissues more than when dilute solutions are used.

Up to the present time injury to the tissues has never been observed following the injection of dilute cocaine solutions. The use of 0.1 to 1 per cent cocaine solutions causes swelling of the tissues. The more dilute the solution the greater the swelling. Injection of 0.1 per cent solution into the cutis is followed by a painful infiltrate, an evidence of tissue injury, whereas if sufficient salt be added to the solution, absorption takes place without damage to the tissue. To prevent swelling following the use of dilute solutions sufficient salt must be added to make its freezing-point the same as that of the blood ($-0.55°$ to $-0.56°$). The freezing-point of a 0.1 per cent watery solution of cocaine varies only $\frac{2}{100}$ of a degree from that of pure water, while a 1 per cent solution freezes at $-0.115°$. By the addition of a 0.6 per cent salt solution to the latter and 0.8 per cent solution to the former both solutions will become approximately osmotically indifferent and will not cause injury to the tissues when used. Injury to the mucous membrane of the mouth, larynx, nose and bladder from the use of solutions of cocaine has not been observed. Injury following the instillation of cocaine into the eye will be described in Chapter XI.

Watery solutions of cocaine are not very stable and are frequently contaminated by the growth of moulds, causing them to become cloudy.

The more dilute the solutions the more quickly do these changes occur, but concentrated solutions are also subject to them. Regarding the sterilization of watery solutions it can be said that a single rapid boiling of a small quantity of a solution is not followed by a material loss of cocaine, whereas the repeated boiling of large quantities of the solution or sterilization in a steam sterilizer causes a diminution in the cocaine content with a diminished activity of the solution.

The operator who has used solutions treated in this manner is not conversant with the greater activity of freshly prepared solutions. To avoid these changes Tuffier advised the fractional sterilization at a temperature of 60° to 70°. It has been claimed by Herissey (Reclus) that watery solutions of cocaine can be sterilized in the autoclave under pressure (115° to 120°) without change, and can be thus preserved for a long time in a sterile condition. According to Dufour and Ribaut cocaine will deteriorate when sterilized by this method if the ordinary alkaline reacting glass vessels are used. It is more advisable when preparing cocaine solutions to make them fresh from tablets just before use, we can then be certain of their uniform action. A simple procedure for the preparation of fresh sterile solutions of cocaine has been suggested by Mikulicz. He dissolves a definite quantity of cocaine in alcohol in a sterile glass flask closed with cotton. After allowing the alcohol to evaporate, the residue is dissolved in water or salt solution.

The Use of Other Cocaine Combinations for Local Anesthesia.—Combinations other than cocainum hydrochloricum have been up to the present time only occasionally used for anesthesia. Bignon believed that the almost insoluble basic cocaine in alkaline solution produced a more intense anesthesia. Inasmuch as the acid salts of cocaine usually contained free acid, it was necessary to neutralize them in the following manner: An excess of sodium bicarbonate was added to a solution of cocainum hydrochloricum. This caused a precipitation of the pure alkaloid which was held in a finely divided state in suspension. This "cocaine milk," according to the reports of Bignon, possessed the most intense anesthetic action, but had to be freshly prepared. The acid salts of cocaine as marketed today are not acid in reaction but neutral. The author compared the action of a 1 per cent watery solution of muriate of cocaine with a like solution of basic cocaine by injecting like quantities into the skin and subcutaneous tissues, and found that the potency of "cocaine milk," both in its action on the sensory nerve endings as well as its action by diffusion, was far behind the muriate of cocaine in its anesthetic effect.

It was likewise found that the duration of anesthesia following injection of basic cocaine into the skin was twelve minutes, while with the usual solution it was double this time. If 0.2 cc of a 1 per cent cocaine solution was injected subcutaneously into cooled tissues, an extensive area would become anesthetized, while cocaine milk used in the same manner never caused the skin at the point of injection to become completely anesthetic. We must, therefore, avoid bringing cocaine solutions in contact with the alkalies.

Tubes of ethyl chloride containing 1 to 5 per cent of the readily soluble alkaloid have been placed on the market (Bolognesi, Touchard, Legrand). If a stream of this fluid is allowed to play upon the mucous membrane of the lip until frozen, it will be observed upon thawing that sensation returns and the mucous membrane has become markedly hyperemic. About five minutes later a gradual and very intense anesthesia of long duration will occur (cocaine anesthesia). This intensity is due to the application of finely divided cocaine crystals left after evaporation of the ethyl chloride. This latter agent at the same time causes a delay of absorption by the chilling of the tissues. These observations upon the action of cocaine ethyl chloride led the author to a closer study of cocaine anesthesia in cooled tissues, the results of which will be described in another chapter. Bolognesi and Touchard recommend this method for the anesthesia of the gums for extraction of teeth, opening of abscesses in the mouth, dilatation of the anal sphincter for hemorrhoids and fissure, and when using the thermocautery on the glans penis and vulva. The method is also very useful in superficial operations on mucous membranes. It has never been successfully proved that cocaine used in this manner could penetrate the unbroken skin, as has been suggested by Legrand. The cocaine ethyl chloride spray applied to the skin acts no differently than pure ethyl chloride. The anesthesia results from cold and not from cocaine. Various cocaine salts prepared by Merck have been tried, such as the salicylate, benzoate, nitrate, and hydrobromate, but they do not possess any advantages over the hydrochlorate.

Space may be taken here for a few words in reference to synthetic cocainum phenylicum (Merck). This is not a chemical combination but a mixture of cocaine and pure phenol, and was obtained by Viau by melting together 1 part of pure phenol with 2 parts of cocaine. The resulting mixture was of the consistency of syrup, and when applied to mucous membranes produced intense local anesthesia without burning. This preparation was not practically applied by Viau, because he used only watery solutions of cocaine with the addition of the phenol. This preparation was again recommended by Oefele, Veasy, and Kyle, and was prepared by Merck according to the formula of Oefele. Cocainum phenylicum is a brown, sticky mass, partially crystalline, insoluble in water, readily soluble in castor oil and alcohol. Alcoholic solutions (cocaini phenyl 1 to 0, alcohol, aquæ dest. āā 50.0) are not suitable for injection, as their action is injurious to the tissues (Reclus); wheals made from this solution become gangrenous. The cauterizing effect of this solution is not due to cocainum phenylicum but to the presence of alcohol. Oily solutions of this substance are absolutely non-irritating and non-cauterizing. The injection of pure olive oil into the cutis is painless; if, however, the oil has been previously sterilized by heat, fatty acids are set free and cause considerable pain on injection. This oil is usually indifferent in its action; if injected into the skin it does not cause any diminution of sensibility and is gradually absorbed without injuring the tissues. If cocainum phenylicum is dissolved in oil its injection into the skin is pain-

less even if the oil has been previously sterilized, and its absorption takes place without any damage to the tissues.

If a 1 per cent oily solution of this preparation is injected into the skin complete anesthesia of long duration ensues (thirty minutes and longer). Five to ten minutes after the injection anesthesia extends a considerable distance beyond the point of injection. By the aid of a small quantity of a 5 per cent oily solution injected subcutaneously, a large area can be made anesthetic and the conductivity of nerve trunks can be interrupted for one to two hours.

It is important to know that these concentrated oily solutions with their intense local anesthetic effect do not cause toxic symptoms following injection, as has been observed after the use of concentrated watery solutions of cocaine hydrochlorate. Regarding the comparative toxicity of cocaine hydrochlorate and phenyl-cocaine, Dillenz has noted death in rabbits following the subcutaneous injection of 0.08 cocaine hydrochlorate, while the same animals injected with 0.3 phenyl-cocaine in oil had only mild toxic symptoms, and death did not occur after the injection of 0.6. Unfortunately the concentration of the solution was not mentioned. Dillenz also reported comparative experiments in the painless extraction of teeth following the subgingival injection of watery solutions of cocaine and solutions of phenyl-cocaine in oil. He found that dilute solutions of the hydrochlorate did not produce the desired result, while the concentrated solutions, as is well known, frequently gave rise to toxic symptoms. The injection of a 4 to 5 per cent solution of phenyl-cocaine in oil always produced results, and in about 700 injections of a 1 to 6 per cent solution general toxic symptoms were never observed. These statements have been verified. If the gums are injected on both sides of the tooth with one-quarter of a syringeful of a 5 per cent solution of phenyl-cocaine in oil, a painless extraction can be performed five to ten minutes later.

There is no doubt that the slight toxic action of this remedy is less dependent upon the phenol than the oily solvent. This can be explained by the fact that watery solutions injected under the skin are rapidly absorbed by the blood stream, whereas oily solutions are more slowly taken up by the lymph vessels. This same action will take place if basic cocaine is injected in an oily solution without the addition of phenol. The use of oily solutions is associated with considerable discomfort.

TROPACOCAINE.

Giesel, in 1891, discovered a new alkaloid in the leaves of the Java coca plant, which in 1892 was synthetically prepared by Liebermann as benzoylpseudotropein and later was given the name of tropacocaine by Chadbourne. The salt of the hydrochloride is practically the only one used. It consists of a white crystalline powder, readily soluble in water, having the formula $C_8H_{14}\ NOC_6\ H_5\ CO\ HCl$.

The solutions are stable and can be sterilized by boiling. For the

sake of brevity tropacocainum hydrochloricum will be designated by the name tropacocaine.

The local and general physiological action of this drug was first studied by Chadbourne. He found that the instillation of a 1 per cent watery solution in the eye was followed in a few minutes by a complete anesthesia of the cornea and conjunctiva, with only a slight degree of mydriasis and no paralysis of accommodation. Anemia of the parts did not occur and symptoms of irritation were only noted after the use of a preparation made from coca leaves, which was entirely absent in the synthetic preparation. Subcutaneous injections of solutions of this new alkaloid produced local anesthesia, and Chadbourne's reports regarding the local action of tropacocaine were soon verified by many observers. This agent in a 2 to 3 per cent solution was soon recognized as a useful, non-irritating anesthetic for the eye by Schweigger, Silex, Ferdinands, Bockenham, Groenouw, Rogmann, Veasey, and others. The absence of paralysis of the pupils and accommodation was considered an advantage over cocaine. Anesthesia occurs very quickly following its use, but is of shorter duration than that following cocaine, the anesthesia, however, can be indefinitely continued by repeated instillations. This substance, however, has not found extensive use in ophthalmology.

For anesthesia of the pharynx, nose, and larynx this drug, according to Siefert, is not so well adapted, as the anesthesia may be insufficient or symptoms of irritation may be very severe. Profuse secondary hemorrhage was also noticed in one case following its use, but how this condition was brought about by this agent is not clear. According to reports of Hugenschmidt, Pinet, Viau, Bauer, Zander, and Dillenz, extraction of teeth can be painlessly carried out by the injection of a 4 to 5 per cent solution into the gums. Custer advised this agent for the Schleich infiltration method, and Schleich used the powder of this agent for anesthesia of freely exposed nerve trunks and the surface of serous membranes as exposed hernial sacs.

A systematic investigation of the local action of tropacocaine injected into the skin has given the following results: The injection of tropacocaine dissolved in 0.8 to 0.9 per cent salt solution is absolutely painless when used in solutions up to 2 per cent. Stronger solutions cause irritation of short duration just as solutions of cocaine. Pure watery solutions of 0.08 per cent and less produce pain owing to the tumefaction from the water. The freezing-point of watery solutions of tropacocaine are as follows:

3 per cent solution, freezing-point	—0.395°
4 per cent solution, freezing-point	—0.540°
5 per cent solution, freezing-point	—0.645°

It will be seen from this table that the physiological concentration of this agent is about 4 per cent, that watery solutions of a lower concentration give rise to the physiological symptoms of tumefaction, while concentrated solutions produce symptoms of dehydration. It is therefore necessary in

using weak solutions of tropacocaine to add sufficient salt to give a solution of 0.6 to 0.9 per cent. The wheals produced by the endermatic injection of this solution become immediately anesthetic, and it has been determined that a solution of 0.01 per cent tropacocaine in 0.9 per cent salt solution possesses marked anesthetic qualities. The wheals produced by the injection of this agent react differently than those produced by cocaine. As a proof of this the author injected into the skin a 0.1 per cent solution of cocaine and a 0.1 per cent solution of tropacocaine in salt solution in such a manner that wheals of the same size are next to one another. Both become immediately anesthetic, but the duration of the anesthetic from the tropacocaine is less than half as long as that from cocaine. It will be found necessary to use a tropacocaine solution of five to eight times the strength of that of cocaine in order to produce an anesthesia of the same duration. It can therefore be said that the action of tropacocaine compared with cocaine is much less intense. It has also been observed that a few minutes after the injection the wheal produced by tropacocaine presents an entirely different appearance from that of cocaine. The latter appears to have become smaller and flatter. The former is accompanied by itching and spreads irregularly in all directions, soon reaching double its original size, and raised above the surface of the surrounding skin. The extension of the anesthetic area does not seem to follow the enlargement of the wheal. The wheal disappears much later than that produced by cocaine. Tropacocaine, therefore, belongs to that group of substances which cause a secondary edema of the tissues into which they are injected. This edema does not seem to be much of a disadvantage inasmuch as it disappears very quickly. It has nothing in common with the edema and infiltration as described by dentists following injections of concentrated cocaine, tropacocaine, eucaine, and other solutions. Concentrated solutions of tropacocaine when injected into the tissues give rise to considerable action at some distance from the point of injection, and differ only from those of cocaine in their shorter duration. If a 5 per cent tropacocaine solution be injected into the skin the tissues for a considerable distance around the border of the area infiltrated become insensitive for a short time.

Infiltration of the subcutaneous tissue with a 0.5 per cent tropacocaine solution causes anesthesia of the overlying skin. Tissue injury following the subcutaneous injection of solutions of tropacocaine of weak and medium concentration have not been observed. The injected solution is quickly absorbed without leaving any mark where injected. The blood contained in the area injected does not seem to be materially influenced.

The results of these experiments seem to show that tropacocaine can be used for local anesthetic purposes when the duration of the anesthetic is of no moment. The inferiority of this agent as compared with cocaine is shown when an extensive diffusive action is desired, as in anesthetizing mucous membranes by local applications. It must also be remembered that a much longer time and much more frequent application of the solution is necessary to produce the desired result. The local application of

tropacocaine, as a rule, produces an anesthesia of too fleeting a nature, and inasmuch as it has not the property of causing anemia, it is unsuitable for use in rhinology and laryngology. If, however, certain precautions are taken to prevent its rapid absorption, as, for instance the ligation of an extremity, then tropacocaine becomes equally as efficient an anesthetic as cocaine. This agent likewise becomes efficient for operations of short duration, if its use is combined with the cooling of the tissues. The general toxic action of tropacocaine is very similar to that of cocaine, producing in animals excitation of the entire central nervous system with severe cortical convulsions which, if not followed by death, causes paralysis. Pulse and respiration are increased in frequency, temperature is elevated, while the blood-pressure falls. The latter is in direct contrast to the action of cocaine which causes the blood-pressure to increase owing to its power of contracting the bloodvessels. The experiences of Chadbourne are not convincing in reference to the action of this drug upon the vagus. Following the administration of fatal doses death occurs from paralysis of the respiratory center. After intravenous injections, even in small doses, cardiac paralysis occurs before respiratory paralysis. The rapidly occurring but transitory action of tropacocaine can be observed in its general toxic action. It is very remarkable to observe in rabbits and guinea-pigs how quickly these animals recover from an apparently moribund condition following the injection of tropacocaine. After the administration of this anesthetic the animals are seized with the most severe convulsions, but in about ten minutes seem to have regained their normal condition.

The toxicity of tropacocaine in experiments on both animals and man seems to be considerably less than that of cocaine. These facts have likewise been verified by Chadbourne, Vamossy, von Pinet, Viau, Dillenz, and Custer. Custer found that it was necessary to inject into rabbits 0.08 of tropacocaine per kilo in 5 per cent solution compared to 0.03 cocaine per kilo in the same concentration to produce severe symptoms of poisoning, and he believes that with the use of very dilute solutions (0.1 to 0.2 per cent) it is possible to inject a maximum dose of more than 0.5. Whether this is correct can only be determined by experiments on man. The author injected hundreds of patients with 0.5 per cent tropacocaine solution in quantities varying from 40 to 50 cc without observing the slightest general toxic action. This is conclusive proof that 0.2 in 0.5 to 1 per cent solutions can be considered a perfectly harmless dose.

If weaker solutions be used this dose can be materially increased. Definite precautionary measures should always be observed for the prevention of general poisoning, the same as after the use of cocaine. Too large a quantity should not be injected into the circulation at one time. Highly concentrated solutions of tropacocaine should not be used for injection or for application to large absorbing surfaces. The advice of Reclus, to have the patient anesthetized with cocaine assume a horizontal position, is not necessary in tropacocaine anesthesia. Serious tropacocaine poisoning has never been observed in man, but such slight secondary

symptoms as dizziness, anemia, fainting, tremor of the extremities, pressure over the heart, and dryness of the throat have been frequently observed by dentists following the injection of 5 to 10 per cent solutions.

Solutions of tropacocaine can be readily sterilized by boiling without change and can be preserved in this sterile condition for an indefinite time without altering their stability. In weak, non-sterile solutions moulds are often observed which may cause a partial disintegration of this alkaloid. This agent has been used almost entirely in lumbar anesthesia.

EUCAINE.

Eucaine, so called by Vinci (but later known as α-eucaine), is an alkaloid which was synthetically prepared by Merling. Its chemical constitution and physiological action upon living animals are very similar to that of cocaine. This alkaloid, having the chemical name n-methyl-benzoyl-tetramethyloxy-piperidin-carboxylic-methyl ester, is only slightly soluble in water but readily soluble in alcohol, ether, chloroform, and benzol. Its hydrochloric acid salt crystallizes in brilliant leaves and plates, and contains one molecule of the water of crystallization as shown in the formula, $C_{19}H_{21}NO_4$ HCl H_2O.

This salt is soluble up to 10 per cent in water of the room temperature. The solutions can be sterilized by boiling and are stable. The general and local action is that of an intense protoplasmic poison. Its toxic action has been studied on animals by Vinci, and has been found similar to that of cocaine. Large doses cause excitation of the central nervous system with tonic and clonic convulsions followed by paralysis (if the animal does not die in the stage of convulsions). Death occurs from respiratory paralysis. This alkaloid seems to be somewhat less poisonous than cocaine, but according to Vinci this difference is not very great. If a 5 per cent eucaine solution be dropped into the eye or injected subcutaneously intense local anesthesia will follow. These observations have been verified by many authorities, but those who have used eucaine practically state that besides anesthesia this agent causes very severe irritation and hyperemia of the tissues, for which reason it is not a suitable substitute for cocaine (Heinze and Reclus). Combinations of cocaine and eucaine (Hackenbruch) possess no material advantages. In fact, eucaine is very seldom used at present.

Of much greater value is another alkaloid, very similar to tropacocaine, which was described by Vinci in 1897, being known as β-eucaine, benzoyl-vinyl-diacetonal-karin. The previously mentioned preparation of eucaine was styled α-eucaine. This nomenclature has caused a number of mistakes which we will shortly describe (Marcinowski). Free basic β-eucaine, like cocaine or α-eucaine, is almost insoluble in water but becomes readily soluble when converted into a salt by combining it with an acid, hydrochloric acid being used in the formation of this salt, which gives rise to the formula $C_{15}H_{21}NO_2$ HCl, a salt of much practical value. For the sake of brevity we will speak of this salt as β-eucaine. It is a white

crystalline powder which dissolves in water to about 3.5 per cent at room temperature. The solution is stable and can be sterilized by boiling without change. It also possesses certain antiseptic properties.

Vinci observed that applications of a solution of β-eucaine to the mucous membrane of the mouth caused anesthesia. If instilled into the eye rapid anesthesia of the cornea and conjunctiva occurred, whereas the pupil and accommodation were not affected. Applications of this agent always caused considerable hyperemia but not as marked as that following the use of α-eucaine. Attempts were now made on all sides to replace cocaine by β-eucaine wherever local anesthesia was desired, as in ophthalmology (Silex), urology (Wossidlo, Legueu), in laryngology and rhinology, and also for injection into the gums in dental surgery (Dumont, Legrand, Keisel, Thiesing), and in general surgery (Braun, Heinze and Reclus). The properties of this agent for local use have been determined by the systematic investigation of Heinze and the author. The results following endermatic injections are almost identical with those of cocaine. The injection of this alkaloid in indifferent solutions is absolutely painless, even 10 per cent solutions (prepared by warming it) causing no symptoms of irritation. The lower limit of activity of this substance is similar to cocaine 0.005 solution producing definite disturbances of sensation following its endermatic injection.

When used in the same manner eucaine anesthesia is usually of shorter duration than cocaine anesthesia. If 0.1 per cent cocaine solution is injected into the skin of a person to be experimented upon, 0.15 per cent β-eucaine solution would be necessary to produce anesthesia of like duration. Concentrated solutions (more than 1 per cent) cause the tissues to become anesthetic for a variable distance beyond the area directly infiltrated. The extent of this diffusion is, however, very much less than after the use of cocaine solution of the same strength. This anesthetic is much less efficient, and acts more slowly than cocaine solutions when applied to mucous membranes and nerve trunks.

In osmotically indifferent and fairly concentrated solutions β-eucaine does not cause tissue injury on injection. Wheals disappear quickly without leaving an infiltrate, but concentrated solutions (10 per cent) are not so well borne by the tissues, painful infiltrations usually remaining after injection. Concentrated solutions of cocaine and tropacocaine act in the same manner. The cause of these symptoms is not only from the substance injected, but also from the physical and dehydrating action of these concentrated solutions. Pure watery solutions of β-eucaine are painless in dilutions as low as 0.04 per cent, the anesthetic preventing the pain of tumefaction.

The freezing-point of various solutions of β-eucaine are as follows:

1 per cent solution, freezing-point	—0.125°
2 per cent solution, freezing-point	—0.245°
3 per cent solution, freezing-point	—0.360°
4 per cent solution, freezing-point	—0.450°

It will thus be seen that the physiological concentration of this agent is about 5 per cent; more dilute solutions when used for injections require the addition of 0.6 to 0.7 per cent of salt, to prevent the consequences of tumefaction. Injections of β-eucaine solutions cause a mild grade of hyperemia in the tissues. The results of these experiments demonstrate that the local anesthetic property of solutions of β-eucaine are in general similar to those of cocaine solutions of slightly weaker concentration. This agent diffuses, however, much less extensively than cocaine but it can be made equal to the latter in this respect by slightly increasing its concentration. Solutions of 3.5 per cent can be readily prepared with warm water, and the salt will not readily precipitate on cooling. The intense toxic action of this alkaloid upon protoplasm even in very dilute solutions must necessarily cause general symptoms of poisoning. This toxic action has been studied by Vinci in animals. He observed after the administration of large doses irritation of the central nervous system, evidenced by convulsions and exophthalmos, which were, however, much less severe than those following cocaine and α-eucaine. Central paralysis was also noted following these symptoms. Death occurred from respiratory paralysis, the heart continuing to beat for a considerable longer time. Besides this action, Vinci noted paralysis of the peripheral motor nerves and the vagus similar to that following the use of curare. Respiration was increased in frequency and only during the stage of convulsions was dyspnea noted. During the stage of paralysis respiration became very superficial, and the pulse slow in consequence of irritation of the motor ganglion of the heart, the blood-pressure falling in consequence of vasomotor paralysis. The toxicity of this drug is far less than that of cocaine. The fatal dose, according to Vinci, following subcutaneous or intraperitoneal injections is:

	β-eucaine.	Cocaine.
Rabbits	0.40 to 0.50	0.10 to 0.12 per kilo
Guinea-pigs	0.30 to 0.35	0.05 to 0.06 per kilo

Dolbeau, Schmidt, Dumont, and Legrand hold that the fatal dose of β-eucaine for animals is 3 to 3¾ times larger than that of cocaine. The author's tests coincide with these results, provided that the concentration of the cocaine and β-eucaine solutions are about the same. Concentrated β-eucaine solutions are more toxic than dilute cocaine solutions. The statements of Dolbeau that β-eucaine injected intravenously is just as toxic as cocaine have been found to be not quite correct. In the author's experiments the difference was materially in favor of β-eucaine. Following the injection of 0.01 cocaine in 1 per cent solution into a vein in the ear of a rabbit weighing 1500 gm. very severe, almost fatal, toxic symptoms occurred; whereas the same quantity of β-eucaine in like solution, injected intravenously into the ear of a rabbit of the same weight, produced no symptoms of poisoning. Just as in cocaine poisoning the concentration of β-eucaine solutions plays a most important part.

A rabbit weighing 2900 gm. was injected under the skin of the back

with 3 cc of a 10 per cent β-eucaine solution (about 0.1 per kilo); clonic convulsions were noted in about five minutes, followed by paralysis of the extremities; the animal lay on its belly with extended extremities; after one and a half hours the animal was to all appearances again perfectly normal.

A rabbit weighing 2800 gm. was injected under the skin of the back with 30 cc of a 1 per cent β-eucaine solution (more than 0.1 per kilo); a slight paralysis of the extremities was noted after about fifteen minutes that entirely disappeared after one and a half hours.

A rabbit weighing 2750 gm. was injected under the skin of the back with 300 cc of 0.1 per cent β-eucaine solution (more than 0.1 per kilo). This injection was not followed by any toxic symptoms.

A rabbit weighing 2090 gm. was injected subcutaneously with 100 cc of a 1 per cent β-eucaine solution (0.5 per kilo); convulsions followed in a short time, death ensuing ten minutes later.

A rabbit weighing 1530 gm. was injected subcutaneously with 750 cc of 0.1 per cent β-eucaine solution. This injection was followed by mild symptoms of poisoning, with convulsions and paresis of the extremities. The animal appeared perfectly normal again in four hours.

To arrive at definite conclusions in regard to this drug, these experiments must be frequently repeated. Just as we observe with cocaine, so also following the use of eucaine in concentrated solutions, the animal may at one time show no evidences of poison while at another it may show mild or severe symptoms from the use of the same dose. Following the subcutaneous injection in a rabbit weighing 2120 gm. of 0.3 per kilo of β-eucaine in 10 per cent solution, there was not the slightest evidence of subsequent poisoning. Eight days later this same dose was injected in the same animal and in the same way, producing very severe symptoms of poisoning. These differences of action from the same doses and of like concentration are undoubtedly due to uncontrollable variation in the rapidity of absorption of the agent. Eucaine poisoning, just as cocaine poisoning, can occur when relatively small doses are introduced into the circulation and will not occur with relatively large doses when they are prevented from entering the circulation.

The same rules must be observed in the use and dosage of β-eucaine as were considered for cocaine. The maximum dose of β-eucaine for man, which of course will vary with dilute solutions, can only be determined by experiments on human beings. It is certainly much larger than the maximum dose of cocaine which can be borne without general toxic symptoms. Results obtained after extensive experiments would indicate that a dose of 0.1 in 1 to 2 per cent solutions would certainly not be considered a large dose and has been materially exceeded by some authorities. Frequently doses of 20 to 30 cc of a 0.5 per cent solution (—0.1 to 0.15) have been given, and 300 cc of a 0.1 per cent solution. The author has never seen a case of β-eucaine poisoning in patients and considers the dose above mentioned harmless. The use of 30 cc of a 10 per cent β-eucaine solution (3 gm.), as advised by Lohmann, cannot be sufficiently deprecated, not

only on account of the quantity but on account of the danger to the tissues after using solutions of this concentration. It certainly is unnecessary for us to again pass through the experiences and injuries which were produced in the early days from cocaine used in a similar manner.

There are no reports in the literature of poisoning from β-eucaine except those following Bier's lumbar injections. The serious consequences following lumbar injections are certainly not entirely due to the absorption of the drug but rather to the local action by contact of the injected solution with the central nervous system. The negative reports from the literature do not indicate by any means that poisoning from eucaine has not occurred. However, it is justifiable when using this agent to observe all necessary precautions. Marcinowski, to whom we are indebted for his interesting studies in regard to eucaine, noticed mild symptoms of poisoning following the injection of a 5 per cent β-eucaine solution into his own thigh (dosage is not given).

The author can report a similar personal observation. For experimental purposes a nerve trunk of the forearm, probably the median nerve, was injected with 1 cc of 3 per cent β-eucaine solution (0.03). In about five minutes nausea, vertigo, and a peculiar weight and weakness of the extremities occurred which compelled him to lie down. These observations were similar to those of Marconowski. In about fifteen minutes all these symptoms had disappeared. It is quite as unjustifiable to use concentrated solutions of β-eucaine for injection into the tissues as concentrated solutions of cocaine and the operator must so perfect his technic that it will not be necessary to use highly concentrated solutions. It is never advisable to exceed a 2 per cent β-eucaine solution for injection. This solution should not be considered weak but rather a concentrated one.

To recapitulate: It can be said that the advantages of β-eucaine over cocaine are its undoubted milder toxic action, its stability, and the possibility of sterilizing by means of boiling. The disadvantages of this preparation are less intense anesthetic action, which in some procedures must be intensified by increasing the concentration of the solution and its mild hyperemic action. Some authorities (Mikulicz) attempt to prevent this hyperemia by mixing eucaine solutions with cocaine.

A short time ago a new eucaine salt was placed on the market, viz., eucainum aceticum. This latter preparation differs from the hydrochlorate salt in its greater solubility in water (33 per cent). According to Cohn, its action on the eye differs but slightly from that of β-eucaine solutions; at any rate, 2 per cent solutions cause very uncomfortable irritation. The author tried this agent on healthy individuals and likewise found that it is more irritating than the hydrochloride of β-eucaine. Whether the concentrated solution will be suitable for anesthesia of the mucous membranes appears doubtful. If the operator desires to have a β-eucaine salt which is readily soluble in water, it would be best to use lactic acid β-eucaine which has recently been tried out. This salt does not differ materially either in its irritating action or anesthetic properties from the hydrochlorate.

HOLOCAINE.

Holocaine was prepared in 1897 by Taeuber by combining molecular quantities of phenacetin and phenatidin. It belongs to the group of the amido compounds (p-diathoxyæphenyl-diphenyl-amidin). Its basic compounds are insoluble in water, whereas the white crystalline needles of the hydrochlorate are soluble up to 2.5 per cent in this liquid. The solutions are extremely sensitive toward alkalies, for which reason they must be prepared in porcelain vessels. Solutions of this drug are stable and can be sterilized in porcelain vessels by boiling (Legrand). Up to the present this remedy has only been used in ophthalmology by Guttman, Hirschfeld, Denneffe, and others. Instillations of holocaine solutions in the eye first cause severe burning followed by a useful anesthesia. Following the endermatic injection severe irritation precedes anesthesia. Holocaine does not possess any advantage over cocaine and β-eucaine and on account of its toxic action should be used with great care. Severe convulsions have been produced in rabbits by the administration of 0.01 per kilo. Pouchet has discarded this agent owing to the variation of the product found on the market. Legrand states that this drug should be stricken from the list of local anesthetics.

ANESON.

In 1898, under the trade name *aneson* or *anesin*, 1 to 2 per cent watery solutions of trichlorpseudobutylalcohol were placed on the market. It has also been known under the name of acetone chloroform or chloretone. According to Vamossy, acetone chloroform when administered in doses of from 0.5 to 1 gm. is without unpleasant consequences. He also recommended this drug for local anesthesia. Impens, on the contrary, claims that it is a very dangerous hypnotic. Aneson is a clear colorless solution with a peculiar mouldy odor all its own. Its freezing-point is $-0.118°$, which would of necessity require the addition of salt to prevent tumefaction following injection. Verified in part by communications from Israi, Grósz, Antal, Bilasko, Vamossy claims that aneson both when applied to mucous membranes and injected into the tissues causes a local anesthesia equal in intensity to a 2 to 2.5 per cent cocaine solution.

Heinze and the author have experimented with this solution and have found that when injected endermatically it causes very severe pain, and the anesthesia which is confined to the wheal lasts only a few minutes. An extension of the anesthesia beyond the border of the area infiltrated never occurs. We were also unable to detect any noticeable effect on the mucous membranes, and just as little effect on the nerve trunks, which refutes the communications of Moosbacher. In areas of the skin infiltrated with aneson the painful infiltrates remain. The activity of aneson is almost completely lost on boiling. We must, therefore, refute the statement of Vamossy that this agent corresponds to a 2 per cent cocaine solution in its local anesthetic action. In comparing this drug with cocaine it

will be found that 0.05 per cent cocaine solution will produce the same local anesthetic effect as aneson. Rubinstein and Sternberg reached the same conclusions when using this drug for purposes of infiltration. If 100 cc of aneson are injected subcutaneously into a rabbit weighing 2700 gm. the rabbit will pass into a sleep lasting twenty-four hours, a death-like sleep; pulse and respiration are for hours scarcely noticeable; the animal recovers gradually. 100 cc of 0.05 per cent cocaine solution never cause such general symptoms. Therefore, aneson, for local anesthetic purposes, should be placed in the obsolete class.

AKOIN.

Under the name of *akoin*, Trolldenier has included chemical compounds similar to holocaine (alkyl-oxyphenyl-guanidine). The akoin of commerce is a hydrochloric acid salt of guanidine, its chemical name being d-p-anisyl-mono-p-phenetyl-guanidinchlorhydrate. Akoin is a white, odorless, crystalline powder of bitter taste, soluble in cold water up to 6 per cent, very readily soluble in alcohol. The solutions are strongly antiseptic. The experiments of Trolldenier, made upon animals, on his own person and other healthy persons, demonstrated that this substances produced intense anesthesia of long duration. A solution of 1 to 2000 produced anesthesia in the eye of a rabbit; the instillation of a 1 per cent solution caused lack of sensation lasting about three-quarters of an hour; a 5 per cent solution produced anesthesia lasting twenty-four hours. Irritation occurred when the solutions exceeded 1 per cent. A 1 per cent solution was sufficient to produce a useful anesthesia in the eyes of horses and dogs, but was not so efficient when used in the eyes of human beings, the irritation being more severe. Endermatic injections made on human beings with a 0.05 per cent solution in normal salt produced an anesthesia lasting thirty-five minutes. When the solution was increased to 0.1 per cent anesthesia lasted forty minutes.

Shortly after the first reports by Trolldenier regarding the action of akoin the author carried out a series of experiments on the endermatic injection of this remedy in healthy individuals and found that it produced a skin anesthesia of unusual duration.

Concentration of the Solution in 0.8 Per Cent Salt Solution and Duration of the Anesthesia.

5% to 1%	0.5%	0.2%	0.1%	0.05%	0.01%	0.005%	0.0025%
Several hrs.	2 hrs.	1 hr.	30 to 40 min.	20 to 26 min.	10 min.	6 min.	4 min.

The duration of akoin anesthesia is many times that of cocaine solutions of like concentration. If akoin in 0.0005 per cent is added to an indifferent salt solution disturbance of sensation can still be determined in the wheal. It will be seen that the lower limit of activity of this substance is considerably below that of cocaine. In testing the sensation after the injection of this substance another material difference is noted from that

of cocaine. Although anesthesia occurs instantly in the skin at the point injected, it requires a half-minute or longer before anesthesia becomes complete in the infiltrated tissues. It will, therefore, be noted that the changes brought about in the nerve substance take place slower but are of much longer duration than following the local use of cocaine. The injection of very weak akoin solutions gives rise to slight pain. Injury to the tissues has not been observed following the use of dilute solutions, but 0.5 per cent solutions cause a painful infiltrate to remain at the point of injection; 5 per cent solutions sometimes cause gangrene of the wheal.

The anesthesia resulting from the diffusion of this substance, as in its application to mucous membranes and in anesthesia of nerve trunks, is much less than that following the use of cocaine solutions of the same concentration. Akoin is a severe poison and great care must be exercised in its use. Trolldenier fed large doses of this substance to animals without noting any toxic effect, for which reason he holds that large doses can be likewise injected in man, but experiments of this kind must be viewed with great skepticism.

Opposing these experiments are those of Thiesing, who found that the fatal subcutaneous dose of akoin for rabbits was much smaller than the fatal dose of cocaine (0.15 cocaine in 1 per cent solution opposed to 0.08 akoin in 1 per cent solution).

The following is a brief record of the author's experiments with the drug on rabbits:

1. A rabbit, weighing 1220 gm.; subcutaneous injection under skin of the back of 6 cc of a 2 per cent akoin solution (=0.1 per kilo); after ten minutes paresis of the forelegs, followed by paresis of the hindlegs. Complete paralysis and difficult respiration followed rapidly. These symptoms continued four hours with apparently no interference with the consciousness of the animal. The animal returned quickly to normal.

2. Rabbit, weighing 1070 gm.; subcutaneous injection into the skin of the back of 2.5 cc of a 2 per cent akoin solution (=0.05 per kilo); in about twenty minutes symptoms same as above, but less intense, lasting one hour.

3. Rabbit, weighing 2150 gm.; subcutaneous injection into the skin of the back of 13 cc of a 2 per cent akoin solution (=0.12 per kilo); convulsions of short duration followed by paralysis; animal was alive twenty-four hours later, completely paralyzed, and was killed with chloroform.

4. Rabbit, weighing 1270 gm.; subcutaneous injection into the skin of the back of 160 cc of a 0.1 per cent akoin in salt solution (=0.12 per kilo); twenty minutes later severe symptoms of poisoning, with paralysis of the extremities. The animal was restored to normal in about six hours.

5. Rabbit, weighing 1800 gm.; subcutaneous injection into the skin of the back of 270 cc of a 0.1 per cent akoin in salt solution (=0.15 per kilo); very severe poisoning with paralysis of all the muscles of the body; death occurred in two hours from respiratory paralysis.

6. Rabbit, weighing 1300 gm.; subcutaneous injection into the skin of the back of 200 cc of a 0.1 per cent akoin in salt solution (=0.16 per

kilo); paresis of the extremities in twenty minutes; in two hours total paralysis; no effect on consciousness. Animal was alive twenty hours later but completely paralyzed and had to be killed.

7. Rabbit, weighing 1590 gm. subcutaneous injection into the skin of the back of 13 cc of a 0.2 per cent akoin solution (=0.164 per kilo); after ten minutes unable to coördinate the movement of the extremities; difficult respiration, followed in fifteen minutes by convulsions of short duration, then paralysis with apparently no change of consciousness. In twenty minutes death from respiratory paralysis.

8. Rabbit, weighing 3040 gm.; subcutaneous injection into the skin of the back of a 2 per cent akoin solution (=0.164 per kilo); death followed in two hours with symptoms as above.

9-10. Dose of 0.2 and 0.7 per kilo in 2 per cent solution was followed in a few minutes by death.

Exact pharmacological experiments with akoin have not been carried out, and lacking their reports all that can be said is that this agent causes a peripheral paralysis similar to that following the use of curare or eucaine, at least the above-mentioned experiments seem to point this way. The symptoms of general akoin poisoning, as has already been noted in connection with its local action, are very stable and of considerable intensity. Medium-sized doses which do not cause immediate death of the animal give rise to a miserable condition which continues unchanged for twenty to twenty-four hours and necessitates the killing of the animal. In this it differs from the effects of cocaine, eucaine, and tropacocaine poisoning, as following the use of these latter drugs the symptoms disappear very quickly. Another point of interest is the fact that the same dose of this agent in either concentrated or dilute solution acts the same, thus differing from cocaine solutions.

The cause of these symptoms seems to be clear. The prolonged duration of the effects of the poison on the organs seems to produce the same effect as when a similar dose of other poisons is rapidly absorbed, thus giving rise to a cumulative action of the drug. The experiments have also shown that the toxic action of akoin is exceptionally severe, certainly not less than that following the use of cocaine. In consideration of the miserable, long-drawn-out symptoms of akoin poisoning from which the animals cannot recover yet take so long to die, it appears that cocaine is by far the least dangerous agent. It is advisable not to exceed the maximum dose of 0.025, as suggested by Thiesing.

Practical use of akoin was first made by Dariet. He found that subconjunctival injections of cyanide of mercury, which were usually very painful, could be painlessly made if small doses of a 1 per cent akoin solution were added to the solution. Cocaine was unsuitable for this purpose owing to the short duration of its action. The value of akoin in subconjunctival injections has been verified by many ophthalmologists (Guibert, Carter, Hirsch, Etiévant). The dentists Senn, Nipperdey, Bab, and Thiesing advised the subgingival injections of a 0.5 to 2 per cent akoin solution for the painless extraction of teeth. Bab advised combining

this solution with that of cocaine, claiming that the action of a 0.5 per cent akoin and 0.5 per cent cocaine solution was as effective as a 5 per cent solution. Spindler praises the long-continued action of a 0.1 per cent akoin solution for Schleich's infiltration anesthesia. The author has also used solutions of 0.05 to 0.1 per cent akoin with 0.1 per cent β-eucaine combined with the requisite amount of salt in various major operations requiring considerable time for their performance.

The β-eucaine was added to these solutions for the purpose of preventing the pain following injections of akoin solution. It is undoubtedly an advantage to use an agent for purposes of infiltration which will produce anesthesia lasting several hours. The use of this solution has been of particular value in hemorrhoid operations in which cocaine and eucaine solutions have often been insufficient. As much as 0.05 of akoin has been used at one dose without injury. It is inadvisable to use solutions for injection into the tissues of more than 0.25 to 0.5 per cent of akoin, as they will without doubt cause injury to the tissues. In most cases sufficient anesthetic effect can be obtained from other agents without this danger.

Just as with holocaine, solutions of akoin are extremely sensitive to even traces of alkalies as, for instance, that contained in glass, for which reason certain precautionary measures must be observed in preparing these solutions. Only distilled water should be used and solutions should be made in porcelain vessels either with cold or lukewarm water, the necessary quantity of salt being added last of all. The finished solution can be sterilized by boiling without deterioration, and can be kept in dark bottles previously boiled in hydrochloric acid and thoroughly washed with distilled water. It is perhaps better to keep watery solutions of akoin in strengths varying from 1 to 2 per cent, diluting them just before use. In the preparation of eucaine-akoin solution, take 25 parts of akoin to 100 parts of absolute alcohol and add 6 drops of this solution to about 0.05 to a 0.1 per cent eucaine solution just before use.

In the preparation of concentrated akoin solutions (1 per cent or more) these alcoholic solutions naturally cannot be used, as the diluted solution will contain too much alcohol. Syringes and needles which have been previously boiled in soda solutions must be carefully washed with water before use. Since the introduction of suprarenin the author has not used this substance and considers it entirely unnecessary, at least for producing local anesthesia for operative purposes, since its only advantage, namely, prolonged anesthesia, can be secured much better by the addition of suprarenin to other substances.

ANESTHETICS OF THE ORTHOFORM GROUP.

(*A*) **Orthoform.**—It has been an open question for some time whether it was necessary to use the complete cocaine molecule for the production of local anesthesia or if parts of this molecule possessed similar action. Working along these lines, Filehne used the alkaloid ecgonin, obtained

from cocaine by the removal of its benzoic acid, and found it to be absolutely inactive, while alkaloids not bearing any relation to cocaine when combined with the benzol group acquire cocaine-like properties. He concluded from these experiments that the anesthetic properties of an alkaloid were absolutely dependent upon the presence of the benzol group in combination. Ehrlich is of the opinion that anesthetic action is only associated with certain bodies of the cocaine group and only those in which the ecgonin ether has taken up certain radicals which might be termed anesthesiphorous.

Stimulated by these experiments Einhorn and Heinz concluded from their investigations that it was characteristic of all aromatic amidoöxyesters to produce local anesthesia. Of all these substances that known as orthoform possessed anesthetic properties in the highest degree (p-amido-m-oxybenzoicacidmethylester). This substance consists of a white powder slightly soluble in water, a property which is of decided advantage in the application to wounds, ulcers, burns, rhagades, excoriations, etc., as a useful anesthetic. It produces an anesthesia of indefinite duration, inasmuch as it is insoluble in the body fluids, at the place of application; it likewise possesses strong antiseptic qualities.

Orthoform exerts its anesthetic qualities only when in contact with exposed nerve ends and remains active for several hours or days. Owing to its slight solubility it cannot penetrate the intact skin or mucous membrane. This agent is apparently only slightly poisonous. Heinz was able to inject 4 to 6 gm. and administer the same quantity internally without any injurious action. Soulier and Guinard found the lethal dose for dogs when internally administered to be 1.0 per kilo, when placed within the peritoneal cavity 0.25 per kilo. The toxic symptoms from this drug are very similar to those of cocaine.

As a local anesthetic in surgery, orthoform is not of practical use owing to its slight solubility and the fact that it readily undergoes decomposition (Heinze). It has been recommended by Klaussner and Neumeyer as a pain-relieving application either in powder form or as a salve for open wounds, burns, ulcers of the stomach, for the relief of pain following extraction of teeth, for pain due to pulpitis, in painful ulcerations of the leg, decubitus, and carcinomatous ulcers. It has been used for long periods of time and in large quantities without injury. Various secondary effects have, however, been noted after the prolonged use of this substance at the point of application, such as erysipelatous reddening of the skin, swelling, vesiculation, local gangrene, eczema, the latter at times spreading over the entire body (Asam, Brocq, Wunderlich, Miodowski, Friedländer, Graul).

Friedländer collected 18 cases in which general symptoms, such as vertigo and vomiting, occurred after the use of orthoform. There have also been unpleasant secondary effects such as have been described following the use of this drug in the treatment of leg ulcers, for which reason this remedy should be used with caution, and before continuing its use it must be tried on each individual patient. It should never be used in

cases of cracked nipples in nursing women on account of injury to the baby (Pouchet). This same author also cautions against the use of this remedy in combination with silver nitrate, owing to its strong reducing qualities, nitric acid being set free.

(*B*) **New Orthoform.**—This remedy is known under the high sounding title of m-amido-p-oxybenzoicacidmethylester, consisting of a fine powder, cheaper than orthoform, but having the same action and secondary effects as this preparation.

(*C*) **Nirvanin.**—Owing to the difficult solubility of basic orthoform and the strong irritating properties from its acid reaction, this remedy was not suitable for local anesthesia, for which reason Einhorn and Heinze attempted to replace the amido atom group of amido ester and oxyamido ester, believing that this portion of the molecule was of secondary importance to other groups of atoms. They found in the hydrochloride of diethylglycocoll-p-amido-o-oxybenzoicacidmethyl ester a salt readily soluble in water, possessing local anesthetic qualities, solutions of which were neutral in reaction and had antiseptic properties. This substance was given the name of nirvanin and consists of a white crystalline powder, solutions of which are stable and can be sterilized by boiling.

Experiments with nirvanin in 0.8 per cent salt solutions when injected endermatically give the following results: The injection is painful but is quickly followed by anesthesia of the wheal. The lower limit of activity of a solution which can cause a distinct diminution of sensation is about 0.05 per cent. This is about ten times the concentration of the weakest cocaine solution which would be active. It was also found that to produce anesthesia of the same duration it was necessary to use about ten times the concentration of a nirvanin solution as was necessary for the cocaine solution; for example, if two wheals are injected next to one another in the skin of a person to be experimented upon, one with a 0.1 per cent cocaine solution, the other with a 1 per cent nirvanin solution, the duration of anesthesia in both is about the same.

Anesthesia by diffusion beyond the borders of the point of injection is not distinctly shown, even after the use of a 5 per cent solution; at any rate it is much less than the diffusion anesthesia following the use of 0.5 cocaine solution. Injury to the tissues has not been observed following the use of nirvanin solutions, it merely causing a slight hyperemia.

The results following the practical use of solutions of nirvanin correspond perfectly with those obtained in experimental tests. The anesthetic properties of a 5 per cent nirvanin solution are too slight to replace cocaine solutions as a local application for mucous membranes. It is not suitable for use in the eye owing to its irritating properties. Nirvanin solutions of 0.25 to 1 per cent can be used for local anesthetic purposes. According to Luxenburger solutions of 2 per cent nirvanin are suitable for the blocking of nerve trunks. The author's experiments and investigations coincide with those of Hoelscher. He found that the activity of nirvanin solutions when injected into nerve trunks cannot be compared to cocaine solutions of similar concentration. Nirvanin solutions of 2 to 5 per cent

act more slowly than 0.2 to 0.5 per cent cocaine solutions and require waiting a considerable time for interruption of nerve conduction even when an extremity is ligated. Weaker solutions are not at all active. The pain associated with the injection of nirvanin is extremely unpleasant. Nirvanin solutions of 5 per cent have been recommended for subgingival injections in the extraction of teeth. Rothenberger has used it in 164 cases, and after waiting three to five minutes was able to extract teeth without pain in 155 of these cases. Stubenrauch discarded the 5 per cent solution owing to the pain following injection, and was able to make teeth sufficiently anesthetic for extraction by injecting a 2 per cent solution. In cases where the alveolar process was very thick or where periostitis was present this agent was absolutely ineffective.

In regard to the toxic action of nirvanin the following has been noted: Luxenburger found that general toxic symptoms occurred following the use of 0.22 per kilo of this substance in rabbits. Joanin claimed that the toxicity of cocaine compared to that of nirvanin is as 1 to 7.5. Didrichson observed a cumulative action of this drug and found that its toxic effects did not bear any relation to body weight. Large animals were affected by small doses and, on the other hand, small animals were often able to withstand very large doses.

The toxic symptoms are similar to all the other drugs previously mentioned, consisting of excitation followed by paralysis. Large doses produced very severe convulsions. Einhorn and Heinze consider 0.5 as the maximum dose in man. Luxenburger considers 0.55 as the maximum. Inasmuch as the dosage for local anesthesia is ten times that of cocaine, the advantages of this remedy must be considered very doubtful. Luxenburger and others have used 0.5 nirvanin in patients without noting any secondary effects. Floekinger observes after a dose of 0.5 vertigo and nausea, which were promptly relieved by the use of 2 mg. of strychnine. Dorn reports a case in which, following the injection of 0.75 cc of a 5 per cent nirvanin solution, extensor convulsions, headache, vertigo, and ringing in the ears occurred. The above mentioned experiments seem to indicate that nirvanin will not have much of a future.

Anesthesin and Subcutin (Ritsert).—Another product of the orthoform group has been devised by Ritsert and is sold under the trade name of *anesthesin*. It is a fine, white, crystalline, non-hygroscopic powder which, when placed on the tongue, gives rise to a sensation of numbness. It is soluble with difficulty in water, readily soluble in alcohol and the fatty oils, and can be used as a salve without deteriorating. This agent, according to Binz and Kobert, is non-toxic and according to the reports of von Noorden and Lengemann can be used for anesthetic purposes in the same manner as orthoform, relieving pain for a considerable period without the secondary effects observed following the use of orthoform. Von Noorden recommends this drug in cases of nervous hyperesthesia of the stomach and ulcus ventriculi. It should be taken ten to fifteen minutes before eating, 2.5 gm. being considered the maximum daily dose. Anesthesin can also be used as an insufflation and inhalation in hyperesthesia

of the larynx, in troches for sore throat and cough due to irritation of the pharynx, in suppositories for tenesmus and painful hemorrhoids, in salve (10 per cent ointment with adeps lanæ), for pruritus, in diabetes, etc. Kassel praises the action of this remedy when used as an inhalation (anesthesin 20, menthol 10 to 20, olei olivarum 100) in hyperesthesia of the larynx. Lengemann, Henius and Becker recommend the drug for the relief of pain in erysipelas, burns, and painful granulations, the drug to be applied alone or in combination with dermatol. Injurious secondary effects have never been noticed.

Solutions of the hydrochloric salts of anesthesin in 0.25 per cent strength were used by Dunbar and Rammstedt for infiltration and conduction anesthesia on the fingers with good results. Ritsert considered the most suitable preparation of anesthesin to be a combination of anesthesin and paraphenolsulfoacid which he called *subcutin*. This is a white crystalline powder, soluble in water to 1 per cent; is stable and can be sterilized by boiling. These solutions are strongly acid in reaction. According to Becker, 0.8 to 1 per cent subcutin solutions are suitable for infiltration and conduction anesthesia of the fingers. Experiments show that by injecting 0.8 per cent subcutin in 0.7 per cent salt solution that the injections are not painful and the infiltrated tissues become immediately anesthetic, the duration of the anesthesia being somewhat longer than following the use of 0.1 per cent cocaine solutions. It was, however, noted that the injections of subcutin produced irritation of the tissues, painful infiltrates always being found at the point of injection. These were occasionally associated with superficial vesiculation. Injecting 1.5 cc of subcutin solution around the base of the fourth finger, which was ligated, required twenty-five minutes for complete anesthesia. This injection was followed by very severe pain which prevented any further investigation in this regard. Subcutin should, therefore, be considered unsuitable for injections into the tissues.

Propæsin and Zykloform.—Propæsin is the propyl ester and zykloform the isobutyl ester of p-amidobenzoacid. Both substances consist of a white crystalline powder only slightly soluble in water. These substances have been used in powder form for dusting on painful ulcerations of all kinds, as a salve (15 per cent propæsin salve according to Stuermer and Lueders, 5 to 10 per cent zykloform according to Straus) for covering painful ulcerations and rhagades and internally for intestinal pain (propæsin 2 gm., zykloform 0.2 to 0.4). The unpleasant local effects observed with orthoform were not noticed following the use of these remedies.

STOVAINE.

Fourneau, of Paris, observed that a number of substances belonging to the amido alcohol group possessed local anesthetic properties. A derivative of this group known chemically as α-dimethylamin-β-benzoylpentanol-chlorhydrate was placed on the market by Billon under the

name of stovaine, and was used by the French, particularly Reclus, as a substitute for cocaine.

Stovaine crystallizes in small, white, glistening leaves, is readily soluble in water, and can be sterilized by boiling, but deteriorates at a temperature of 120°. The pharmacological properties of this drug were studied in experiments on animals by Billon and Pouchet. They found stovaine to be poisonous to the central nervous system, the same as cocaine, after the administration of toxic doses. In herbivorous animals general analgesis was noticed in a few cases without other nervous symptoms. In other cases, as in dogs and cats, these latter symptoms were more prominent, evidencing themselves by paralysis of the extremities, incoördination of movements, and circular movements. Central tonic and clonic convulsions resulted in respiratory paralysis and death either immediately or after a comatose state. The body temperature of guinea-pigs was subnormal, while in dogs and cats it was normal or elevated.

This drug acts as a stimulant to the heart and has a dilating effect on the bloodvessels as stated by Billon. According to Pouchet the dilatation of the bloodvessels and the lowering of the blood-pressure is soon followed by normal conditions. Four per cent solutions of stovaine applied to freely exposed nerve trunks cause an interruption of conductivity, but not so complete as after the application of cocaine (Pouche). Laewen has demonstrated that a 5 per cent stovaine solution applied to the freely exposed sciatic nerve of frogs, causes irreparable damage to the conductivity of the nerve, and even after the use of a 4 per cent solution he was able to prove that a return of conductivity in the nerve trunk never occurs. The toxicity of this new agent is supposed to be two to three times less than of cocaine. Reclus is the only one who has had extensive experience in the practical use of this drug for injection into the tissues. He used a 0.5 to 1 per cent solution for purposes of infiltration and states that 0.2 to 0.3 is without danger and can be used as a substitute for cocaine. For anesthesia of the mucous membranes stovaine up to the present time has not been extensively used. According to Lapersonne the instillation of 0.5 to 2.5 per cent solutions into the conjunctival sac is painful and the resulting anesthesia is not so complete nor of so long duration as cocaine anesthesia.

The author has tested the action of this drug upon himself and other healthy persons by injecting solutions into the cutis and subcutaneous tissues. The results were as follows: 0.1 per cent solution with the addition of 0.8 per cent salt, intracutaneous injection of the forearm; injection was painful. The wheal became immediately anesthetic; duration of anesthesia five or six minutes. Hyperemia followed at the point of injection. The duration of anesthesia of a neighboring wheal made with 0.1 per cent cocaine solution lasted fifteen minutes.

One per cent solution with the addition of 0.6 per cent salt. Injection was very painful; very marked and lasting hyperemia at the point of injection; duration of anesthesia eight minutes. Duration of anesthesia in the neighboring wheal made with 1 per cent cocaine solution was about twenty-four minutes. No marked evidences of tissue injury, but the

disappearance of the wheal was not so free from reaction as that produced by cocaine.

Five and 10 per cent stovaine solutions, subcutaneously injected. Injection extremely painful. The resulting wheal anesthesia did not disappear, and the entire wheal as far as the subcutaneous connective tissue became gangrenous.

The subcutaneous injection of 1 per cent stovaine solutions in the fore-arm and neighborhood of the radial nerve produced a distinct effect upon the peripheral branches of this nerve. Stovaine is not to be compared in efficiency with cocaine, eucaine, or tropacocaine solutions of the same strength. The injection of stovaine solutions in a ligated finger produces the same results as cocaine solutions of much weaker concentration. The finger, however, remains painful and swollen for several days, whereas the injection of cocaine, tropacocaine or β-eucaine causes no reaction. Stovaine, according to the author's investigations, even in 1 per cent solutions, causes injury to the tissues. Sinclair observed gangrene in 4 cases following the use of a 2 per cent solution. These results stamp this agent as unsuitable for local anesthesia, a conclusion with which Reclus agrees.

ALYPIN.

This drug recommended by Impens is very similar to stovaine. Stovaine is the hydrochloric acid salt of benzoylæthyldimethylaminopropanol, and alypin is the hydrochloric acid salt of benzolethyltetramethyldiaminopropanol, and is derived from the former by the substitution of $N(CH_3)_2$ for the hydroxyl radical. This substance consists of colorless crystals very readily soluble in water, forming neutral solutions which can be sterilized by boiling. In regard to the chemical and pharmacological properties of alypin reference is made to Impens' reports.

Experiments with Alypin.—1. 0.1 per cent alypin solution with addition of 0.8 per cent salt. Formation of wheal on the arm of a healthy person. Injection is painful, and the wheal becomes immediately anesthetic. Sensation returns in about eleven minutes. The wheal becomes slightly hyperemic immediately after injection. Following the injection a markedly hyperemic infiltrate remains for several hours.

2. Control experiments with 0.1 per cent cocaine solution with addition of 0.8 per cent salt. Formation of a wheal next to the alypin wheal. Injection is painless and the wheal becomes immediately anesthetic. Sensation returns in about fifteen minutes. The wheal is anemic; there is no infiltration or hyperemia.

3. 1 per cent alypin solution with 0.8 per cent salt. The injection is painful. The anesthesia lasts about twenty minutes. At the point of injection a painful infiltrate remains for several days.

4. Control experiment with 1 per cent cocaine solution with addition of salt. Injection is painless, the anesthesia lasting about twenty-five minutes; the injected solution is absorbed without leaving any noticeable effect.

5. 5 per cent alypin solution. Injection is very painful, the anesthesia, which is quite extensive around the wheal, lasts about thirty-seven minutes; at the point of injection the epidermis is raised in the form of small vesicles. A superficial layer of the cutis became gangrenous, for which reason the 10 per cent solution was not tried for this purpose.

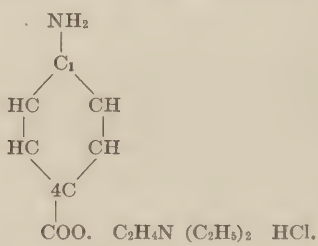
6. 1 per cent alypin solution. Injection of 1 cc in the form of a transverse strip under the skin of the forearm. In about ten minutes there is a very pronounced effect upon the subcutaneous nerves from the solution resulting in a marked diminution and in places complete loss of sensation in their area of distribution. In about fifteen minutes sensation returns to normal.

It was noticed that this agent, like stovaine, produced marked local anesthetic effects. The hyperemia following the injection was slight. The toxicity of this agent, according to Impens, is less than that of cocaine. More recent experience has cast great doubt on the correctness of this statement. Unfortunately, the injection of alypin is painful, and the intracutaneous and subcutaneous injection is frequently accompanied by very noticeable tissue injury. The latter, however, is not so marked as following the injection of solutions of stovaine. Laewen has demonstrated that nerve trunks poisoned with a 5 per cent solution of alypin can be restored to normal by washing out this solution, which in the case of stovaine is impossible. For these reasons the use of solutions of alypin for injections is contraindicated, inasmuch as we have other agents without the local injurious effects. Alypin has been successfully used as an anesthetic for mucous membranes in rhino-laryngological practice (Siefert, Ruprecht), and also in urology (Joseph, Kraus, Lucke, Lohnstein, Garasch). Garasch, in 1453 cases of alypin anesthesia, observed severe poisoning following the injection of 5 cc of a 2 per cent and also a 5 per cent solution into the urethra. One and a half to two minutes after the injection, dyspnea, nausea, vomiting, vertigo, mydriasis, hallucinations and convulsions occurred, pulse and respiration could not be counted, and only after energetic efforts at resuscitation for eighteen to twenty-two minutes did the patient show evidence of returning vitality. These toxic symptoms are very likely to occur according to his experience in young debilitated persons. Proskauer observed a death after injecting 20 cc of a 20 per cent solution into the bladder. The patient was seized with tonic and clonic convulsions immediately after the injection and died soon thereafter. Schröder saw 2 cases of severe poisoning in operations on the accessory sinuses of the nose. In 1 case 13 cc and in the other 18 cc of a 2 per cent solution of alypin were injected into the ethmoidal and maxillary nerves as well as into the wall of the antrum, and the mucous membrane of the nose and of the sinuses was sprayed with a 15 per cent solution of alypin and treated with cotton tampons saturated with the same solution. The solution contained suprarenin. Shortly after the operation, convulsions, somnolence, suspended respiration, and cyanosis appeared. Both patients recovered. These misfortunes induced Schröder to test again the toxicity of alypin on animals. The following results

were obtained: For guinea-pigs the lethal dose of alypin injected subcutaneously was twice as large (0.1) as the lethal dose of cocaine (0.05–0.06); while for rabbits the lethal dose injected subcutaneously was about the same for each. The lethal dose of alypin for rabbits injected intravenously is also about the same as that of cocaine. Both substances behaved very similarly in that the lethal dose injected intravenously is very much smaller than the lethal dose injected subcutaneously. The uncertain and disproportionate effects noted in the use of like doses of cocaine pertain also to alypin. In an addendum to the supplementary volume of the *Deutschen Arzneibuch*, the maximum dose of alypin is given as 0.05, the same as for cocaine. This is based on the unpublished experiments of Lewin. What is said above (page 76 to 92) concerning cocaine poisoning applies equally well to alypin poisoning. Great caution is urged in the use of this substance injected into the tissues. If it must be injected, the concentration of the solution should not exceed 0.2 per cent. When used on mucous membranes, the same precautionary measures must be taken as in the use of cocaine, namely, the use of the weakest solution limited to the smallest area possible. G. Ritter reports 1 death from alypin. A sixteen-year-old girl was given 1.5 gm. adalin, thirty minutes later 1.5 cg. morphine preparatory to a thyroidectomy. The operative field was injected with 50 cc of a 2 per cent alypin solution. Ten minutes later the patient became unconscious; convulsions, followed by respiratory and cardiac paralysis, resulted after a few hours in death.

NOVOCAINE (PROCAINE).

Chemical Properties.[1]—The chemical properties of this drug were discovered by Einhorn. This preparation is a monochlorhydrate of p-aminobenzoyldiethylamino-ethanols with the graphic formula



The salt crystallizes from alcohol in the form of needles which melt at a temperature of 156°. It is soluble in equal quantities of water, producing a solution neutral in reaction. It is soluble in 30 parts of cold alcohol. From watery solutions, corroding alkaline carbonates of the free base are precipitated as colorless, sometimes crystalline, oily substances. By the addition of sodium bicarbonate clear watery solutions can be made. The free base crystallizes from dilute alcohol with two molecules of the water of crystallization from ether or ligroin; it crystallizes

[1] From the Hoechster Farbwerken.

in water free, shining prisms. The melting-point of the water-containing base is about 51°, that of the water-free base about 58 to 60°. With the general alkaloid reagents, as potassium iodide, calcium mercury-iodide, picric acid, this preparation even in very dilute solutions is precipitated. Watery solutions of novocaine can be boiled without deterioration and can be kept in tightly-stoppered flasks for days without change of color. The physiological concentration is about 5.48 per cent.

The pharmacological experiments as carried out by Biberfeld have given the following results: In animals it was found that the preparation anesthetizes well and very promptly, 0.25 per cent solutions being sufficient to cause an anesthesia of ten minutes in a freely exposed nerve. When used locally, this drug has no secondary effects, and even after the use of very concentrated solutions, symptoms of irritations were not observed. Powdered novocaine can be sprinkled upon fresh wounds in delicate structures, such as the cornea, without irritation; whereas stovaine applied in this manner immediately cauterizes the tissues. The general effect following the use of medium-sized doses is very slight. Doses of 0.15 to 0.2 per kilo when introduced subcutaneously in rabbits produce scarcely any noticeable change in the curves for blood-pressure and respiration on the revolving tambour. If novocaine is injected intravenously, the blood-pressure sinks and the respiration becomes slow and superficial. The fall of blood-pressure is apparently due to the influence of the substance upon the vasomotor centers. The heart does not seem to be affected and likewise no peripheral action upon the vessels is noted. The toxic action of this drug is less than from any hitherto known anesthetic substance.

Fatal doses per kilo of body weight following subcutaneous injections are as follows:

	Cocaine.	Stovaine.	Novocaine.
Rabbits	0.05 to 0.1	0.15 to 0.17	0.35 to 0.4
Dogs	0.05 to 0.07	0.15	0.25 is not fatal

Intravenous injections.

	Cocaine.	Stovaine.	Novocaine.
Cats	0.018	0.025 to 0.05	0.15 not fatal

Laewen's experiments have shown that the function of a nerve trunk paralyzed by the application of a 5 per cent novocaine solution returns quickly to normal after the washing out of the medicament. The author's experiments have given the following results:

1. 0.1 per cent isotonic novocaine solution. Formation of wheal on forearm. Injection was painless. Wheal became immediately anesthetic. Anesthesia, as with tropacocaine, was of very short duration; after about three to five minutes sensation returned to normal. No hyperemia. The wheal disappeared without leaving any evidence of its existence.

2. 0.5 to 1 per cent novocaine solution. Injection painless; duration of anesthesia ten and fifteen minutes respectively. The wheals disappear without any injury to the tissues.

3. 5 to 10 per cent novocaine solution. Injections of 5 per cent solution were painless, 10 per cent solution caused very slight irritation; duration

of anesthesia about seventeen to twenty-seven minutes very slight hyperemia at the point of injection; the wheals disappeared without any evidence of infiltration or sensitiveness.

4. 1 per cent novocaine solution. 1 cc was injected subcutaneously in the forearm in the region of the superficial radial nerve; the sensation of the skin immediately over the point of injection was diminished shortly after the injection. There was no noticeable effect upon the peripheral branches of the nerve.

5. 0.5 per cent novocaine solution. Ligation of the fifth finger with a rubber band; injection of 1 cc of solution around the base of the finger in the subcutaneous connective tissue. In about eleven minutes the finger as far as the tip was completely anesthetized. Five minutes after the removal of the rubber band sensation returned. The finger experimented upon showed no secondary swelling or sensitiveness.

It will be noted from these results that we have to do with an agent similar to tropacocaine having marked local anesthetic properties, not, however, having the same duration as many other similar substances. We find for the first time since the discovery of eucaine that we have in novocaine an anesthetic possessing scarcely any irritating properties. After the injection of 10 per cent solutions of this substance endermatically it is found that they are absorbed without leaving any secondary effects. There is no peripheral effect on the bloodvessels; this has also been observed by Biberfeld. 10 per cent solutions cause very slight irritation with slight hyperemia, just as any other concentrated hyperosmotic salt solution will produce purely by its physical properties. In the light of these experiments it would be said, very properly, that novocaine, owing to the rapid disappearance of its anesthetic effects, could not compete with cocaine. Laewen has similarly expressed himself. Experience and experiments have, however, shown that by doubling the dose of novocaine, so as to make it as effective as cocaine, and at the same time by adding certain substances, which will be described in the next chapter (suprarenin), novocaine has become an ideal anesthetic for injection into the tissues and has made the use of cocaine unnecessary. This agent has been introduced into England by Arnold, Struthers, and Le Brocq; in America by McArthur, Schley, and others; in Russia by Spisharny. In France the school of Reclus has given up stovaine and taken up novocaine.

In a recent communication regarding his experiments Piquand, a pupil of Reclus, states: "Novocaine at present seems to be the local anesthetic of choice. Its slight toxicity permits of the injection of large doses without danger, and the carrying out of complicated operations which were performed with difficulty or not at all with cocaine. Though having marked anesthetic power, it is neither irritating nor does it have any dilating effect upon the bloodvessels. The only disadvantage of novocaine as an anesthetic is its short duration, which, however, can be rectified by the addition of small doses of adrenalin, causing the anesthesia to become more pronounced and of longer duration without adding to the toxicity of the drug."

Piquand also verified experiments regarding the use of novocaine and

suprarenin made in 1905 by the author and many others. The field of local anesthesia has been materially enlarged and its possibilities in surgery have been greatly extended. For the anesthesia of mucous membranes novocaine is not so well suited, as it penetrates this structure with much more difficulty than cocaine and some other substances.

It has already been mentioned, in describing the work of Gros, that the bases of anesthetic substances are much more active than their salts, and the activity of the salts is greater the weaker the acid contained in them. In the light of these experiments, Laewen conducted practical experiments and concluded that novocaine bicarbonate solutions produce a more rapid anesthesia and conduction anesthesia of longer duration than novocaine hydrochloride. A conclusion in which the author, as a result of his own experiments, cannot concur. The preparations of novocaine phosphates and novocaine borates as used by Gros in animal experiments were found to have very strong anesthetic properties, but owing to the injury to the tissues it was impossible to use these substances. The interesting studies of Kochmann Zorn and Hoffmann on the effects of combined drugs led to the discovery that the local anesthetizing properties of novocaine were greatly increased by the addition of 0.4 per cent of potassium sulphate to the solution. The author's investigations have proven the correctness of these observations. No explanation has been given of this peculiar property of potassium sulphate of increasing the effects of novocaine. Since potassium sulphate in the concentration mentioned produces neither local nor general harm, there is no objection to the practical employment of the potassium sulphate-novocaine solution. It is impossible to state the maximum dose of novocaine any more than we were able to state the maximum dose of cocaine, eucaine, and other similar agents. The toxicity of this drug as with many others depends more upon the concentration of the solution and the method of its use than on the dose.

In surgical practice the 0.5 per cent to 2 per cent solutions are the only ones used, as a rule. The solutions in combination with suprarenin, as recommended for use by many authorities, are the following:

Nast-Kolb injected about 50 cc of a 1 per cent solution, von Lichtenberg 50 to 60 cc, Axhausen has used 170 cc and has even gone as high as 200 cc (2. novocaine), Chaput 110 cc. Borchardt has used 150 cc of a 0.5 per cent solution, Hesse 250 cc. Since learning the harmlessness of this agent we have been using more of the solution, instilling daily from 100 to 200 cc of a 0.5 per cent solution in connection with small quantities of a 1 per cent solution and repeatedly going as high as 250 cc (1.25 gm.).

Secondary effects from these large doses, except occasional vomiting, have not been observed by the author. However, in some clinics and surgical institutions, as the author has learned from personal communications, secondary effects amounting to collapse have been observed even after the use of small doses of a 0.5 per cent novocaine-suprarenin solution. In other institutions such secondary effects have not been observed. The following explanation may be offered, namely, perhaps too little attention has been given to the instability of the suprarenin. The novocaine solution must contain the usual amount of suprarenin, and the

suprarenin must be active in order that it may delay and limit the absorption of the novocaine. Without the addition of suprarenin the doses of novocaine used by us are inadmissible. One must never forget that novocaine is a poison. Regarding the use of more highly concentrated novocaine solutions, Krecke has injected subcutaneously 2 cc of a 20 per cent solution without injury. Liebl, in experiments upon himself, injected 0.75 cc of a 10 per cent solution into his thigh; in five minutes very mild symptoms occurred, consisting of a sudden peculiar warmth over the entire body, particularly in the region of the liver, slight nausea and vomiting with general unrest; there was no change in the pulse or color of the face. Two minutes later slight deafness was noted in the left ear; accommodation of both sides, but particularly that of the left, was only possible with much effort; double vision occurred; thirteen minutes after the injection there was a slight sticking headache of the left side. Seven minutes later paresthesia in the area of the radial nerve ensued, followed in about one-half hour by a return to normal. Solutions of this strength must not to be used in surgery.

Laewen and others have observed typical novocaine poisoning following the injection of 20 to 25 cc of a 2 per cent novocaine solution into the sacral canal. The symptoms consisted of nausea, sweating, anemia of the face, rapid pulse, frequent respiration, repeated vomiting, a feeling of oppression and a haze in front of the eyes. We have never noticed any disturbance following the subcutaneous injection of 2 per cent solution. These disturbances from sacral injections can be avoided by a slow injection of the solution (Laewen, von Gaza). The slight toxicity of novocaine can be best illustrated by the experiment of Laewen on the nerve trunks of the lower extremities. Laewen has injected as much as 2.1 gm. novocaine, in 1 case the patient received 20 cc of a 4 per cent solution, in another 30 cc of a 2 per cent solution. He has also injected as much as 50 cc of a 1 per cent solution or larger quantities of a 0.5 per cent solution. The injections were distributed over a period of time varying from ten to fifteen minutes. In only a few cases were toxic symptoms noticed.

Dentists have noted symptoms of various kinds in hysterical and nervous persons, as, for instance, sensory paralysis of long duration, and prolonged periods of sleep, which were supposed to be due to the toxic effect of novocaine. Fischer has critically reported on these results. Moeller has described a death occurring in the practice of a dentist, Balzer, which was supposed to be due to novocaine. A girl, aged twenty-three years, with periostitis of the lower jaw. Injection of 3 cc of a 2 per cent novocaine solution with the addition of suprarenin. Following the extraction of the tooth the patient did not feel well; she rested an hour and a half, then stood up and talked excitedly. After an hour and a half she again lay down complaining of dizziness; six hours after injection her condition became worse; eight hours after the injection the patient died in coma, with symptoms of cardiac weakness. Fischer believes that this was a case of acute sepsis, but it could not be definitely proved. The author (with Moeller) believes that without an autopsy, which was not made in this case, that it was impossible to arrive at definite conclusions,

but he stated that it was difficult to conceive of a death following the use of so small a quantity of novocaine, since this agent was used in surgery in fairly large doses without serious consequences. Two very remarkable observations are reported by Claus. In the first case a cotton tampon containing 6 drops of a 10 per cent novocaine solution and 3 drops of adrenalin was placed in the nose of a young woman. The tampon was removed in about twenty minutes and the antrum was washed out. Almost immediately after this procedure the patient became cyanotic and died of paralysis of the heart. There was no diseased condition found in any of the organs at autopsy.

In a second case a woman, aged thirty-six years, had inserted into the lower and middle portion of the nasal tract a tampon wet with a few drops of a 10 per cent novocaine and suprarenin solution. Besides this there was a local application of a 10 per cent cocaine solution applied to the mucous membrane of the nose. Following the anesthesia the antrum was punctured and inflated; the patient collapsed and died the same evening. Autopsy showed numerous hemorrhages into the heart muscle and into the gray cortex of the cerebrum and cerebellum. It is difficult to conceive how Claus can state that this was a case of acute novocaine poisoning, inasmuch as the severe symptoms did not follow the application of this agent but rather occurred following the puncture of the antrum. Claus at the same time reports 2 cases of a similar kind which were operated upon without an anesthetic, in one of which serious symptoms of cyanosis and dyspnea occurred, and in the other apoplexy followed puncture of the antrum. At any rate these observations teach that the slightest operative procedure can be followed by dangerous complications which cannot be attributed to any one thing but must be explained by a combination of circumstances.

Under the old methods of using local anesthesia severe toxic symptoms were observed so seldom that the use of novocaine was looked upon as almost without danger. Severe and occasional fatal secondary effects have been observed more frequently in recent times since the use of large doses of novocaine by other methods in the solution of new problems. These secondary symptoms are delirium, somnolence, in which the sensibility of the entire body is extinquished (A. W. Meyer), convulsions which appear immediately after the injection and which are an almost certain indication of an intravenous injection, and collapse. Such symptoms have been observed almost exclusively following injections in the neighborhood of the vertebral column, in paravertebral anesthesia in the neck and back, and in splanchnic anesthesia. (See Sections 12 and 14.) Thirteen of the cases in which severe symptoms were observed occurred in blocking the cervical plexus in the neck. Two of them were observed by the author himself.

A boy, aged fifteen years, collapsed suddenly just as the injections down to the transverse processes of the cervical vertebræ were begun. The pulse was scarcely perceptible, the eyes were wide open, the pupils dilated and the respirations accelerated. The boy cried out constantly,

"It roars in my head." He was entirely normal in a few minutes. The injections and operation were completed without further disturbance.

The second case was that of a young hysterical girl who collapsed at the end of the injection. In this case at the end of two days we were able to perform the operation with the same method of anesthesia without incident.

Dr. Specklin, of Mühlhausen, communicated 2 more cases to the author.

Two girls, aged twelve and twenty-two years respectively, developed very threatening symptoms soon after injecting down to the transverse processes of the cervical vertebræ. After artificial respiration and the injection of heart stimulants, the symptoms subsided in the course of fifteen to thirty minutes.

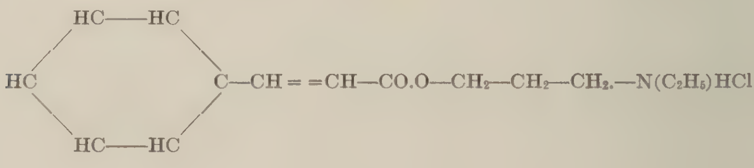
A. W. Meyer saw 2 cases of convulsions and somnolence in strumectomies, due probably to the intravenous injection of the solution. Similar cases have been mentioned by Förster, Wiemann and Hering.

In 3 cases sudden death occurred from paralysis of the heart. (Brütt, Wiemann, Hering.)

It should be noted that these misfortunes occurred after the use of small doses of novocaine and shortly after beginning the injection, but they have not been observed in blocking the brachial plexus above the clavicle, which is not much farther removed from the spinal column. The author does not believe that these unfortunate results were all due to a similar cause. In part they may have been due to intravenous injection, the vertebral bloodvessels having been injured; in part they may have been due to forcing the fluid into the spinal canal. This was shown by Kappis to have occurred in 1 case of paravertebral anesthesia in the back. Wiemann concluded that the symptoms observed by him were due to vagus irritation, and he was able to produce marked temporary slowing of the pulse, which he attributed to vagus irritation, in a series of experimental injections which were not followed by operations. It is not quite clear why similar symptoms should appear relatively so frequently in paravertebral anesthesia in the back and in splanchnic anesthesia. We shall see later whether and how these symptoms may be prevented.

APOTHESINE.

Apothesine is one of the newer local anesthetics brought out during the war. It is described as essentially a combination of cinnamic acid and propyl alcohol and is chemically designated as hydrochloride of gamma-diethyl-amino-propyl-cinnamate, having the following formula: $C_{16}H_{23}O_2N$ HCl or



It occurs in the form of small white crystals, having a melting-point of 137° C. It is readily soluble in water and in alcohol but only slightly soluble in acetone or ether. A solution of apothesine in distilled water is neutral to litmus and is precipitated from solution by alkalies and the ordinary alkaloidal reagents. Solutions may be sterilized by boiling without danger of decomposition. It is less toxic than cocaine, being in this respect in the same class with procaine (novocaine). While its toxic coefficient is low, deaths have occurred from its use intraspinally as well as by injection, so that the same precautions should be observed in its use as in the use of all other local anesthetics. The anesthetic properties of apothesine are about equal to those of procaine (novocaine) and its effects are just as lasting, but as it is somewhat less diffusible, its action is slightly slower. It may be used in strengths ranging from 0.25 to 2 per cent, depending on circumstances and the nature of the case. For most ordinary surgical operation a 0.5 per cent solution sufficies and to the solution may be added sodium chloride to an isotonic solution or potassium sulphate and calcium chloride, as mentioned under novocaine, but sodium bicarbonate or other alkalies must be avoided as alkalies are incompatible with apothesine. Solutions of apothesine are non-irritating to the tissues and no local reaction follows their use. As a topical application to mucous membranes the action of apothesine is very much inferior to that of cocaine, but for nerve blocking and infiltration anesthesia in surgery it is a very valuable and useful agent. Some form of epinephrin, as for instance 6 drops of adrenalin chloride 1 to 1000, should be added to 100 cc of the solution before being used.—[Ed.]

Other Anesthetics.—The anesthetic properties of *carbolic acid*, which is one of the few substances capable of penetrating the unbroken skin, have long been known. Pirrie advocated the use of carbolic acid compresses (carbolic acid 1, oil 6) for extensive burns, the pain being relieved in about ten minutes. Van der Weyde noted that carbolic acid was used in America for a long time for the relief of pain in carious teeth, and Rae reports that the pain of bee-stings could be immediately relieved by the hypodermic injection of carbolic acid (1 to 100). Bill and Smith were the first to recommend compresses and applications of carbolic acid to the skin for surgical purposes. Smith painted the skin of the forearm with 85 per cent carbolic acid; this was followed in a few minutes by burning, after which the entire thickness of the skin could be cut without any sensation. This drug has also been used with success as a local anesthetic in the opening of superficial felons. It was observed in the hospital of the Rudolf Stiftung in Vienna that the injection of 1 to 3 per cent carbolic acid gave better local anesthetic effects than injections of morphine. Caspari used a 2 per cent solution of carbolic acid subcutaneously with very good results. Walser was able to produce very decided local anesthetic effects by the use of a spray of a 3 per cent carbolic acid solution. Richardson recommended for local anesthesia ether sulphate 75, carbolic acid 0.3 in spray form, claiming to be able to produce a much more intense action than by the use of pure sulphuric ether. Schleich also used on

circumscribed areas of mucous membranes and on the freely exposed nerve trunks in operative wounds a 5 per cent carbolic acid solution as a local anesthetic to cause anesthesia in these parts. Strongly irritating carbolic acid can hardly be considered today, inasmuch as we possess so many other more suitable drugs.

Besides the previously mentioned substances there are a number of other drugs to which anesthetic properties are ascribed. Concerning saponin sufficient has been said on page 25. Mays found that with brucine, an alkaloid similar to strychnine, the cornea could be made insensitive following the application of 5 to 20 per cent solution. Seiss was able to verify these observations and used this drug in 5 per cent solutions in furuncles of the auditory canal, in suppurative processes of the middle ear for the purpose of introducing instruments into the ear. Further observations in regard to this remedy are not at hand.

Stenocarpin or *gleditschin,* an alkaloid supposed to be derived from the gleditschia triacanthus, according to the investigations of Goodmann and Claiborne, acts as a mydriatic and local anesthetic when applied to the eye. Novy, investigating this drug, proved it to be an "industrial humbug," and that the supposed 2 per cent gleditschin solution was a mixture of cocaine chlorhydrate, atropin sulphate, and salicylic acid. The presence of an alkaloid in gleditschin is denied.

Local anesthetic properties were also observed by Steinach and Panas with *strophanthin, erythrophlein, helleborin, convallarin, adonidin, dionin, peronin,* and many other substances which are more or less impractical owing to their local irritating qualities and the damage to the tissues, and, in case of some of them, to their general toxic symptoms. Erythrolphlein was tested practically in 1888 and caused Liebreich to give expression to the paradox, "anesthetica dolorosa." Guaiacol was recommended by L. Championniere as a local anesthetic, but owing to its severe irritating properties and the fact that it causes gangrene of the tissues, it is unsuitable for local anesthesia (Reclus). The same applies to gaujazyl, recommended by O'Followell (Heinze).

Antipyrin solutions, which according to the investigations of Heinze are not suitable for injection into the tissues, were used by Lydston for anesthetizing the mucous membrane of the bladder and urethra (10 per cent antipyrin with addition of 1 per cent carbolic acid). Kocher used for anesthesia of the larynx a solution of 5 per cent cocaine with 5 per cent antipyrin and 1 per cent carbolic acid. Ephraim advised the use of 2 per cent antipyrin and 1 per cent solution of chinin bimuriatic carbamid for anesthesia of the mucous membrane of the upper air passages.

In more recent times, Dalma prepared an alkaloid from the Indian plant *gasubasu* and named it neurozidin, which was supposed to possess very marked local anesthetic properties. Magnani found that the alkaloid *yohimbin,* derived from yohimbehe bark, produced anesthesia of the cornea and conjunctiva when instilled into the eye. Loewy and Moeller investigated this remedy more closely, and found that a 1 per cent solution interrupted the conductivity of motor and sensory nerve tracts (sciatic

and vagus). Just as with cocaine the sensory nerves were interrupted before the motor nerves. The action of this drug is transitory and the return to normal takes place rapidly. Marked irritation following the use of this remedy was not observed. According to Oberwarth, 0.05 per kilo injected subcutaneously caused death in rabbits, and inasmuch as severe symptoms are produced in man by the use of 5 mg. of this drug, it must be used with great caution. This drug owes its value to its supposed action on the male genital organs, causing hyperemia and prolonged erections. The local anesthetizing properties of quinine solutions were thoroughly investigated by the author in 1897, but the results did not warrant him in recommending this substance for practical use. Recently Schepelmann has used quinine solutions as a local anesthetic and quinine-urea-hydrochloride solutions seem to be well liked in England and America. The author has tried the different substances, including the quinine alkaloid studied by Morgenroth and Ginsberg as well as the quinine-urea tablets received from England. A solution of these tablets, if not too weak, produces an anesthesia of long duration, when injected into the tissues, but of the preparations used all had an irritating and harmful effect on the tissues.

The value of the various substitutes for cocaine can be judged from the following résumé. The requirements of local anesthetics are as follows: 1. The substance must be less toxic than cocaine in proportion to its local anesthetic power. The determination of a lessened toxicity is not sufficient, for if its anesthetic property be less than cocaine proportionately larger doses will be necessary to attain the same results as with the latter drug; all known substitutes, with the exception of akoin, fulfil more or less these requirements.

2. The agent must not cause the slightest irritation or tissue injury but must, like cocaine, be absorbed from the place of application without any secondary effects such as severe hyperemia, inflammation, painful infiltrates, or necrosis. Only when these conditions are fulfilled can we assume that the healing of wounds will not be interfered with. The use of strongly acid or alkaline reacting substances is not permissible, inasmuch as they cause local tissue injury. On account of this important requirement many of the newer anesthetics have failed in their purposes. The only local anesthetics not causing tissue injury besides cocaine are tropacocaine, eucaine (apothesine—Ed.), and novocaine. Several others, such as alypin, cause so little damage to the tissues that their use for certain purposes (superficial application to mucous membrane) comes into consideration.

3. The agent must be soluble in water and its solutions stable and possible of sterilization by boiling. These requirements are met by all previously mentioned substances, except cocaine, which only in part meets the conditions.

4. It must be possible to combine the agent with suprarenin, as will be described in the next chapter. Cocaine, alypin (apothesine—Ed.) and

novocaine meet this requirement, but all other agents interfere to some extent with the action of suprarenin.

5. For particular places of application, as, for instance, mucous membranes, the anesthetic must be able to penetrate rapidly, its anesthetic properties being dependent upon this quality.

Novocaine and alypin are the two substances which have made the use of cocaine in surgery almost obsolete. Eucaine has been superseded by novocaine, and the use of tropacocaine and stovaine is now almost entirely limited to lumbar anesthesia. The other substances had best not be used as anesthetics for operative work, inasmuch as they all have disadvantages without possessing any advantages over those just named.

CHAPTER VIII.

FURTHER AIDS TO LOCAL ANESTHESIA. THE INFLUENCE OF THE VITALITY OF THE TISSUES UPON THE LOCAL AND TOXIC ACTION OF LOCAL ANESTHETIC AGENTS.

LOCAL anesthetic substances acting upon living tissues, in which the vitality—that is, chemical and physical changes—is artificially interfered with, and the circulation is disturbed, cause a much more intense local poisoning than in tissues with undisturbed, active metabolism and normal circulation. This increase of local action is brought about: (1) By delaying the absorption of the poison from the point of application, thus allowing much longer time for local action. (2) By inhibiting all of those processes by means of which living tissues are able to defend themselves against the intrusion of foreign substances and to bring about a return to a normal condition after having been affected by them. With the increase in intensity of the local action there must be an accompanying diminution in the general toxicity from the substance because (*a*) the absorption of the poison is delayed; because (*b*) much of the poison is destroyed locally and therefore does not enter the circulation. The knowledge of substances which produce an artificial diminution or suspension of vitality and which cause a diminution of the parenchymatous absorption is of much importance to local anesthesia.

To a certain extent the dilute solutions of Schleich used for infiltration of the tissues belong to this class. By means of these dilute solutions the quantity of the anesthetic can be evenly divided over a considerable area and thus be more slowly absorbed, permitting the tissues to come in better contact with the agent than if a similar quantity had been injected in more concentrated solution. The dilution of the solution increases both the toxic and fatal dose of the anesthetic. It will, therefore, be seen that the dilution of the solution increases the local effect and diminishes the toxic action of the substance.

The rapidity of absorption can be diminished and the local effect increased, together with diminished toxicity, if the anesthetic is dissolved in oil instead of water. The absorption of solutions in oil, which takes place through the lymphatics, is much slower than watery solutions, which are taken up directly by the circulation. Legrand and Hartwig recommend that gelatin be added to the anesthetic solutions used for injection. This has likewise been advised by Klapp to delay absorption. Contrary to these recommendations the author has failed to note an increase in the local effect from cocaine by the addition of gelatin. The solutions were

of course carefully sterilized, which, according to Klapp, so alters the gelatin that its property of delaying absorption is lost. On this account the practical application of this method cannot be considered. We possess, however, three other important aids to local anesthesia which can be considered in this connection: The hindrance or interruption of the blood stream by means of ligating the extremities, the use of a substance causing a contraction of the bloodvessels (suprarenin), and the cooling of the tissues by means of the ether or ethyl chloride spray after the injection of the local anesthetic. We will consider these methods in the order named.

THE EFFECTS OF MECHANICAL INTERRUPTION OF THE CIRCULATION ON LOCAL AND GENERAL POISONING.

If a small quantity of a watery solution of coloring matter, such as eosin, be injected into the cutis of the forearm of the person to be experimented upon in such a manner as to produce a wheal, it will be noticed in the beginning that the wheal alone is colored; in a few minutes the extension of the coloring will be noted in a variable area of skin around the wheal, depending upon the concentration of the color solution used. The coloring matter has been diffused and has caused a local reaction that can be noted from the coloring of the tissues. On the other arm of the same person the same quantity of the color solution is injected in the form of a wheal, but immediately before or shortly after the injection the upper arm is constricted with a rubber band. It will be noted that the visible coloring of the skin area in the ligated arm is decidedly larger than in the one which has not been ligated; the color solution has extended into the surrounding area to a great extent and in large quantities. There must have been a hyperabsorption of the color solution at the point of application, and there must necessarily have been less absorbed into the general circulation.

If now a 1 per cent cocaine solution is injected into the skin of the forearm in like manner, an anesthetic wheal will remain for a variable length of time. If the arm is ligated before or immediately after injection, anesthesia of the skin will be distributed in a considerable area beyond the wheal, a result only possible in unligated extremities by using a very concentrated solution of cocaine. From these results it will be noted that the anesthetic action of cocaine has been increased. This can only be explained by assuming that hyperabsorption has taken place at the point of injection. The anesthetized tissues remain in this condition as long as the circulation is interrupted and even some little time after the removal of the rubber band. Only after the return of the circulation do reparative changes begin which are necessary for a return of the tissues to normal. As has already been noted, it is probable that a disintegration of the cocaine has taken place. Since the work of Corning (in 1885), the Esmarch bandage for ligating extremities and thereby increasing the local action of cocaine has come into general use as an important aid to

local anesthesia. The tight bandaging of an extremity, continued for a long time, by interfering with the metabolism of the part and by the compression of nerve trunks, must necessarily aid in diminishing sensation.

With the increased local action and delay of absorption of cocaine on account of the ligature a lessening of toxicity must necessarily occur.

If 0.1 per kilo of a 10 per cent cocaine solution is injected into the hind legs of two rabbits of the same weight, after first ligating the leg of one of the rabbits with a rubber band, the rabbit with the unligated leg, as a rule, dies in severe convulsions in a few minutes, while the rabbit with the ligated leg shows no evidence of poisoning. If the band be released after half an hour mild symptoms of poisoning occur, which, however, do not cause the death of the animal. In fact, in some cases the animal remains perfectly normal. The typical course of this experiment also mentioned by Kummer was long known to the author, therefore one need not too closely question the priority of Kohlhandt, who, induced by the experiments of Czylharta and Donath on strychnine poisoning in animals first systematically investigated this subject. He noted that the general toxicity following the injection of usually fatal doses of cocaine was diminished or entirely prevented by the ligation of the leg of a rabbit, the intensity depending upon the length of time the leg was ligated. If the ligature remained in place for an hour or longer all symptoms of poisoning were avoided. These observations are explained by the fact that, absorption being prevented, disintegration of the cocaine occurred at the point of injection. It has been observed by Kleine that absorption following tight ligation of a limb is not entirely prevented but only delayed.

We are indebted to Klapp for his valuable investigations regarding parenchymatous absorption. He used for this purpose a locally indifferent substance such as milk sugar, which, following its injection, rapidly appeared in the urine. He used this observation to determine the rapidity or delay of absorption. He was able to repeatedly demonstrate that active hyperemia increased the rapidity of absorption, whereas a slight passive hyperemia, such as is produced by the application of a rubber band to the extremities, or following simple elevation, caused a delay in the absorption of the injected milk sugar. Both of these means, either simple elevation or the application of a rubber bandage, caused a marked increase in activity of local anesthetic substances like cocaine and similar drugs.

THE EFFECT OF INTENSE CHILLING OF THE TISSUES ON LOCAL AND GENERAL POISONING.

Another means for diminishing the local vitality of the tissues and delaying absorption is brought about by cooling with either the ether or ethyl chloride spray. By this means it is possible to increase the local activity of various drugs, which can be readily observed in connection

with local anesthetic substances. In a previous chapter intense and long-continued anesthesia was described following the application of cocaine in ethyl chloride. This was not due to the simple combination of cocaine anesthesia with the anesthesia from cold, but to the increased local effect of cocaine from the cooling of the tissues. This same effect can be noticed if a mucous membrane is frozen after a watery solution of cocaine hydrochlorate is applied. The transitory anesthesia from cold disappears rapidly to be followed, however, by a very intense cocaine anesthesia in a very few minutes. If it is desired to combine cocaine with anesthesia from cold in a practical manner the mucous membrane should first be chilled and then cocainized, or the cocaine ethyl chloride spray can be used. While waiting for the action of cocaine to begin, a second chilling of the surface is carried out before operation. The action of cold can also be tested in the increasing local anesthetic effect upon the wheal.

Experiment 1.—Two wheals are injected with 0.5 per cent cocaine solution next to one another on the arm of the person to be experimented upon, both immediately becoming anesthetic. One of these wheals is then chilled until frozen, the second is undisturbed. In the latter wheal sensation returns in about eighteen minutes, and the anesthesia has been confined to the wheal. In the one which had been frozen the duration of anesthesia is about double that of the latter. Five minutes after the injection the anesthesia from cold disappears, the skin is hyperemic, and anesthesia is found to have extended for some distance beyond the point of injection, so that an area of about double the size of the original wheal becomes insensitive. After about ten minutes this secondary anesthesia disappears. Similar symptoms occur if the skin is frozen just before injection.

Experiment 2.—Two wheals not widely separated from one another on the arm of the person to be experimented upon are injected with 0.5 cc of a 0.5 per cent cocaine solution. The area about one of the wheals is frozen, the other being left undisturbed. In the case of the one in which the surrounding area has been frozen anesthesia persists for twenty minutes; in the second wheal this action does not occur.

Both of these experiments readily demonstrate that decided increase in the action of cocaine is produced by the cooling of the tissues. Other local anesthetics show similar results. This method of increasing cocaine activity by the joint use of ether or ethyl chloride sprays has been successful for some time in practice, as, for instance, in the extraction of teeth (Wiener, Schleich, and others). The combination of cocaine anesthesia with the ethyl chloride spray has been very extensively used by Schleich and Hackenbruch. It is important to remember that the anesthetic action of cold with cocaine anesthesia permits the use of dilute solutions of cocaine in tissues where an intense and long-continued anesthesia is necessary, which without cold could only be produced by using much stronger solutions. The knowledge gained from these facts should be of practical value in the development of the art of local anesthesia. If cooling of the tissues diminishes their vitality, thereby delaying absorp-

tion and increasing the local activity of various drugs, it must likewise diminish or prevent the general toxic action of these substances.

The fact that cooling delays parenchymatous absorption, whereas an increase in temperature increases it, was long known and in almost daily use by physicians. It has again been demonstrated in a very interesting manner by Klapp in his experiments with milk sugar. The effect of the chilling of the tissues on absorption and the general action of poisons was demonstrated by Kóssa following the reports of Claude Bernard and L. Brunton.

Kóssa injected into the ears of rabbits, which had been cooled to a temperature of +5° to +7°, potassium cyanide, strychnine, and picrotoxin in doses which, in the control animals, produced death, or very severe symptoms of poisoning. With continued cooling of the parts the injection did not produce the slightest symptom of poisoning and when the cooling was stopped at the end of one and a half hours symptoms did not occur. These same results can be readily determined with solutions of cocaine.

Experiment 3.—Rabbit, weighing 1450 gm.; the skin of the back having been freed from hair was chilled with the ether spray, following which 0.15 (=0.05 cc per kilo) cocaine in 10 per cent solution was injected and the cooling was continued at the point of injection by means of an ice-cap filled with ice and salt. Symptoms of poisoning did not occur. After one hour the cooling was stopped. Ten minutes later mild symptoms of poisoning occurred, such as excitement and paresis of the extremities. Convulsions and coma did not occur. The animal appeared perfectly normal in about fifteen minutes. A control animal injected in the same manner with 0.05 cocaine per kilo but without chilling exhibited in five minutes the usual symptoms of acute cocaine poisoning, with convulsions and coma. Death, however, did not occur.

Experiment 4.—A third rabbit, injected with 0.1 per kilo cocaine in 30 per cent solution, in an area of the back which had been freed from hair and cooled with the ice-bag, showed severe symptoms of poisoning but did not die. These symptoms occurred about seventeen minutes after the injection, following which the cooling was stopped; severe convulsions and coma now occurred but the animal rapidly returned to normal. The injection of 0.1 cocaine per kilo in 30 per cent solution injected subcutaneously is, without these additional measures, an absolutely fatal dose.

These experiments can be continued to further advantage in the following manner: A rabbit is placed in a close-fitting box, a small hole being sawed in one side and the unshaven hind leg drawn out and fixed in this opening. The leg is surrounded with wet cotton and placed in a vessel containing ice.

Experiment 5.—Rabbit weighing 1800 gm.; 10.30 o'clock freezing of the hind leg begun; 10.40 o'clock injection of 0.18 cocaine in 20 per cent solution subcutaneously in the middle of the upper leg, above the bandage holding the leg in place. The point of injection is cooled with the ether

spray followed by covering the leg with wet cotton and ice. No symptoms of poisoning occur; 11.40 o'clock the cooling is stopped and the animal freed; 11.45 mild symptoms of poisoning, as excitement and paresis of the extremities, convulsions and coma do not occur; 12.05 o'clock animal is apparently normal.

Control experiment: Rabbit, weighing 1900 gm.; the animal is confined in like manner and 0.19 cocaine in 20 per cent solution injected. In five minutes severe convulsions occur, death following six minutes after the injection. These experiments clearly prove that cocaine is absorbed so slowly from tissues whose vitality has been diminished by cooling that general poisoning does not occur so long as the cooling is continued, and when the cooling is discontinued after some time the symptoms of poisoning if any are very much attenuated.

The cooling of the tissues upon the local toxic action of anesthetic substances is of much practical interest, but it must always be kept in mind that even with its use the same care as has already been mentioned must be observed.

THE EFFECT OF SUPRARENIN (ADRENALIN) ON LOCAL AND GENERAL POISONING.

From an entirely unexpected source, surgery, and particularly local anesthesia, has been offered a drug the local application of which causes a contraction of the bloodvessels, rendering the tissues bloodless and diminishing their vitality, thereby causing an increase of the local action of drugs and a diminution of their general toxic action. Early in 1900 the author read in a medical journal that a substance had been extracted from the adrenals of animals that would cause the bloodvessels to contract. A few days later he received some of this extract, mixed it with a solution of cocaine and injected the mixture into his forearm. He realized at once that a new era for local anesthesia had arrived.

We have known since the early important work of Brown-Séquard that the removal of both suprarenal glands in animals caused death, and that when this did not occur, it was to be explained only by the presence in the animal of an accessory suprarenal gland. The fresh or dried suprarenal glands of healthy animals contain a toxic body (Pellacani, 1879) having a peculiar pharmacological action when administered to animals or man, and as partly described by Vulpian in 1856, possesses definite chemical reactions. Solutions of this gland or the fresh gland itself rapidly become red or brown when exposed to the air. They become green upon the addition of ferric chloride, again becoming red with the addition of alkalies or the halogens, these reactions being similar to those for guaiacol.

Attempts were made by many experimenters to isolate the active principle of the suprarenal gland, the experiments of Fuerth and Abel coming nearer the solution of this problem than any previous workers. They each prepared an extract of suprarenal which, though not identical,

possessed the same physiological and chemical characteristic reactions. Fuerth called his preparation suprarenin and Abel called his epinephrin. In the year 1901, Takamine and Aldridge, independently of each other, succeeded in separating the active principle of this gland in crystalline form, the product being known as adrenalin.

Fuerth was able to demonstrate that his suprarenin was identical with adrenalin. Suprarenin was first placed upon the market in pure crystalline form by Parke, Davis & Co., of Detroit, Mich., under the name of adrenalin. It is now prepared by a large number of German and foreign (to Germany —Ed.) pharmaceutical houses, both in crystalline form and in the form of a 1 to 1000 solution, and marketed under the various trade names of adrenalin, suprarenin, eudrenal, epirenan, paranephrin, tonogen, etc. The action of all these various preparations is identical, but we have chosen the one known as suprarenin for our work.

Pure basic suprarenin is a white or slightly red or brown crystalline powder possessing the properties of an alkaloid. It is soluble with difficulty in cold water but readily soluble in hot water. It does not deteriorate at a temperature of 100°, and combines with the acids to form salts. In attempting to dissolve this substance in water the solutions are promptly colored red or brown, owing to oxidation of the suprarenin by the oxygen of the air. Solutions remain clear and colorless in a vacuum. By the addition of hydrochloric acid to the solvent, solutions remain clear and uninfluenced by boiling (Braun). Suprarenin is extremely sensitive to the action of alkalies. Synthetic suprarenin has been prepared by the Hoechster-Farbwerke.

After the chemical constitution of suprarenin was determined by Aldrich, Pauly, Stolz, and Friedmann, the chemists Stolz and Flaecher, of the Hoechster-Farbwerke, were able to produce suprarenin-like substances from guaiacol. This substance possessed the same contractile power on the bloodvessels and the ability to raise blood-pressure as the organ preparations and showed the same pharmacological properties only in a lesser degree. The first pharmacological investigations of this product were carried out by Meyer, Loewi, and von Biberfeld.

The hydrochloric acid methyl-amino-ethanol-guaiacol compared in chemical and physiological reactions very closely to those of the organic suprarenin, possessing, however, only about half the physiological activity of the organ preparation. There was another physical difference observed between these two preparations: The organ preparation rotating polarized light to the left, whereas the synthetic preparation was optically inactive, which according to chemical nomenclature is called racemform. Flaecher was able to convert the optically inactive synthetic suprarenin into two components, one being optically dextrorotary (dextrogyre) and the other being levorotary (levogyre). The latter is similar to the organ suprarenin. These two components were designated D-suprarenin and L-suprarenin. The latter product, synthetic L-suprarenin, is identical in its pharmacological reactions with organ suprarenin, as has been demonstrated by the investigations of Cushing, Abderhalden, Mueller, Thies, Slavu. The

author has used for several years the synthetic preparation made by the Hoechster-Farbwerke, which he has tested as to its power of contracting the bloodvessels and whether it could be used as a substitute for the organ suprarenin. It was found suitable, but larger doses were necessary than with the use of organ suprarenin. This preparation was not stable either alone or in combination with novocaine, for which reason within a short time we again used the organ suprarenin. The investigation of the newer products was taken up with much misgiving, first using D-suprarenin, which showed so little contractile power on the bloodvessels that it was not suitable for operations; the L-suprarenin, however, which is marketed under the name of synthetic suprarenin, we have used for some time in the same form and the same dosage as the organ suprarenin and have been unable to determine any difference in its action from the latter preparation.

Double inguinal hernia operations have been used as a test for these drugs, one side being anesthetized with the usual novocaine solution with the addition of organ suprarenin, the other side being anesthetized with a similar quantity of novocaine to which was added the preparation to be tested. The operator was, therefore, in a position to prove the identity of action of L-suprarenin with organ suprarenin. These investigations, which were carried on for many years by German chemists, were of immense importance in a practical way, inasmuch as the cleanliness and constancy of action of a synthetic preparation are more certain than a preparation made from organs removed after slaughter.

The most noticeable effect following the use of the juice of the suprarenal gland or its extracts is a transitory rise of blood-pressure, infinitesimal doses being sufficient to bring this about (according to Moore and Purinton, 0.000000245 to 0.000024 of the extract per kilo for dogs). The cause of this rise of blood-pressure is due to the direct stimulation of the heart (Gottlieb, Hedboom, Schaefer) and to the contraction of the arteries and capillaries of the body. The smooth muscle fibers of other organs are influenced in like manner. According to Jacoby, Boruttau, and Pal the peristalsis of the bowel following the intravenous administration of suprarenal extract is stopped. Lewandowski has shown that the intravenous or subcutaneous injection of suprarenal extract causes the contraction of the smooth muscle fibers of the skin, so that in the hedgehog the bristles rise up. The hair can also be seen to bristle following the use of this substance in cats. Schaefer has stated that extracts of suprarenal cause a contraction of the musculature of the uterus. In large doses this substance is a severe poison and causes the death of the animal experimented upon in a short time with paralytic symptoms and pronounced fall in blood-pressure, the latter being preceded by a rise in blood-pressure.

Cybulski caused death in rabbits after the intravenous injection of 1 cc of a 10 per cent solution of the extract, but this dose could be borne without causing any disturbance if it was diluted ten to twenty times. The active substance can be found in the urine fifteen minutes after a subcutaneous injection (Cybulski, Bardier, and Fraenkel), and following

the administration of fatal doses Blum and Zuelzer found glycosuria constantly present.

The question whether the action of this substance on the smooth muscle fibers, particularly those of the bloodvessels, was of central or peripheral origin has been decided in favor of the latter. Biedl observed in excised organs, such as the kidney and extremities, through which physiological solutions containing suprarenal extract were passed, a contraction of the bloodvessels to such an extent that the flow from the veins ceased entirely. Hedboom and Schaefer observed the direct action of this substance upon the heart excised from a mammal; the organ began to pulsate after the application of suprarenal extracts. Bates, Dor, Darier, and Koenigstein noted the contraction of the bloodvessels of the conjunctiva following the instillation of the extract into the eye. The same observation was made in connection with other mucous membranes, and Velich observed the anemia-producing power following local application of suprarenal extracts to granulating wounds—eczema and burns—in both animals and man. From these results we must believe that the contraction of bloodvessels is of peripheral origin.

It is interesting to note that the bloodvessels of various organs react more or less intensely to the action of suprarenin. The action is very marked in the skin, less intense in the stomach, intestines, and bladder, and not at all upon the vessels of the lungs (Langley, Brodie, and Dixon). Its action on the coronary vessels does not cause contraction but rather dilatation (Langendorff). Laewen has proved that suprarenin is destroyed by the living bloodvessel walls, so that poisoning of the body from this substance is overcome by this action.

The anemia-producing properties of suprarenal extracts have proved of much value in laryngological and rhinological operations for the purpose of allaying hemorrhage (Swain, Moure, Brindel, Harmer, Rode, Rosenberg). Following the application of 1 to 1000 to 1 to 5000 solutions of suprarenin to the mucous membrane of the nose or larynx, turgescence is diminished at once, so that the cavities and accessory cavities become more accessible. The mucous membrane becomes gray and completely bloodless, so that no bleeding occurs after cutting.

Lermoyez called this substance "Alkaloid der Esmarchschen Blutleere." These remarkable observations following the subcutaneous injections of suprarenal solutions have been further tested in healthy persons by experts and the effects have been studied in its almost daily use in operations. It was shown that tissues freely infiltrated, according to Schleich's method, with a 1 to 1,000,000 suprarenal solution became bloodless in a few minutes. There was also noticed an absence of parenchymatous bleeding on cutting these tissues, whereas the arterial and venous bleeding was markedly diminished. Following the injection of stronger suprarenal solutions arteries of larger caliber, as, for instance, the arteries of the finger, were closed completely by the contraction of their lumen. We are in position to cause a circumscribed anemia of the tissues of long duration by means of suprarenin which is not far behind that occasioned

by the constriction of an Esmarch bandage. This action of suprarenin is one which has long been sought in surgery. It is now possible to carry out all operations, wherever necessary, without the loss of blood. This was formerly only possible on the extremities. The anemia can be produced with extremely small doses of suprarenin; 5 drops are sufficient of a 0.1 per cent suprarenal solution to 100 cc of salt solution which contains this substance in a dilution of about 1 to 600,000. A fraction of a milligram of suprarenin is sufficient to make a large operative field bloodless, provided this agent is freely injected in very dilute solution and evenly divided in the tissues. It is not necessary to saturate the operative field with suprarenin solutions. The field will become much more bloodless if the area around the operative field is injected with suprarenin solution, thus cutting off its blood supply, as it were. The technic of the injection is similar to that which will be described later for anesthetizing operative fields. B. Mueller recently described the value of suprarenin anemia in operations upon the parenchymatous organs such as the liver and kidney. His observations upon the human liver have been proved incorrect. This organ has been infiltrated repeatedly with suprarenal solutions in cholecystectomies and injuries to the liver without showing any difference in the bleeding. This is only what should be expected from the rigid non-contracting liver veins.

The blood-checking property of the juice of the suprarenal gland has long been known to those employed in slaughter-houses. It has been stated that in the slaughter-houses at Leipsic the butchers would frequently apply the juice squeezed from the suprarenal gland to wounds for the purpose of stopping hemorrhage.

Suprarenin is of importance in local anesthesia owing to its anemia-producing properties. Suprarenin is not an anesthetic, but local action of other drugs is made much more intense if combined with it. It has been frequently observed by ophthalmologists (Dor, Darier, Koenigstein, Lichtwitz, Landolt, and others) that cocaine, holocaine, atropin, eserin, and other drugs act much more intensely upon the conjunctiva of the eye if combined with suprarenal extract or if the latter had been previously instilled into the eye. Rhinologists and laryngologists (Swain, Bukofzer, Rode, and others) observed the same results, particularly following the use of cocaine. The value of suprarenal extracts in local anesthesia for the extraction of teeth was observed by Carpenter, Peters, Minter, Battier, Nevrezé, and Moeller. As a result of the exhaustive studies made with suprarenin this substance has proved to be a very valuable aid to anesthesia.

It was observed that the local anesthetic power of cocaine solutions was enormously increased by the addition of very small quantities of suprarenin. Dilute cocaine solutions with the added suprarenin acted much more intensely than concentrated solutions without this addition, and anesthesia was observed in tissues far beyond the point infiltrated. The conductivity of nerves was readily interrupted, this being observed even in those mixed nerves which were usually very resistant to the action

of cocaine. At the same time the duration of cocaine anesthesia was prolonged for hours. The extent of the anemia of the tissues and anesthesia are independent of one another. The first depends upon the suprarenin content while the latter depends upon the quantity of cocaine in the solution.

Further experiments were undertaken to determine the effect of suprarenin upon β-eucaine and tropacocaine. It was observed that both eucaine and tropacocaine interfered with the action of the suprarenin in contracting bloodvessels. This was noticeable with tropacocaine, as already mentioned by Rode. The addition of suprarenin to solutions of

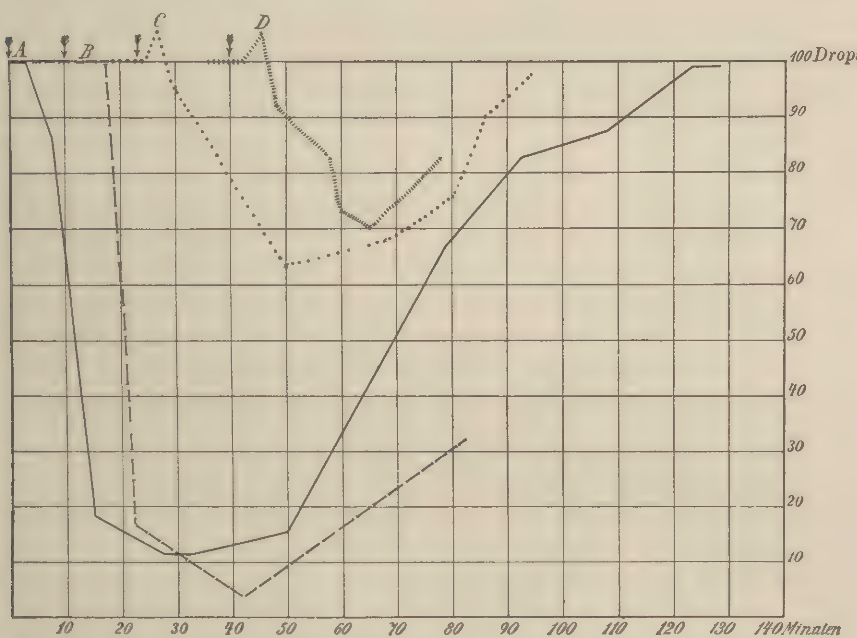


Fig. 6.—The influence of local anesthetics upon suprarenin in reference to its contractile power upon the bloodvessels (Laewen). *A*, suprarenin; *B*, suprarenin with cocaine; *C*, suprarenin with eucaine; *D*, suprarenin with tropacocaine.

eucaine does not cause an increase in the intensity of its action to the same extent as is noted with solutions of cocaine. The addition of suprarenin to tropacocaine solution is of very little value. The effect of these three agents upon the action of suprarenin is well shown in the curves drawn by Laewen.

Laewen, by means of a cannula fastened in the aorta, flushed the vessels of the hind leg of an animal under constant pressure, the fluid dropping out of the vena cava. The rapidity of flow from the vessels under constant pressure was determined by counting the number of drops per minute.

Fig. 6 shows the results of these experiments. The abscissa gives the

time in minutes, the ordinate the rapidity of flow (drops per minute). For the sake of clearness the normal number of drops is reduced to 100 per minute. The arrows indicate the time of beginning the flushing with the different experimental solutions.

Curve A.—0.002 mg. of suprarenin is added to 10 cc of indifferent solution (Ringer's solution with the addition of 1 per cent gum). The number of drops sank rapidly from 100 to 11, which again reached the normal after flushing with Ringer's solution. An interesting observation was made when using pure cocaine solutions for flushing, a fact which, however, had already been determined by Kobert, Brodie, and Dixon, and this was that cocaine solutions alone do not cause contraction of the bloodvessels when passing through them.

Curve B.—Solution of 0.002 mg. suprarenin and 0.01 gm. cocaine in 10 cc of Ringer's solution. The rapidity of flow fell promptly from 100 to 3 drops, which rapidly approached the normal after flushing with indifferent solution.

Curve C.—Solution of 0.002 mg. suprarenin and 0.01 gm. of β-eucaine in 10 cc of Ringer's solution. The rapidity of flow fell from 100 to 63 drops per minute.

Curve D.—Solution of 0.002 mg. suprarenin and 0.01 gm. tropacocaine in 10 cc of Ringer's solution. The rapidity of flow dropped from 100 to 70 drops per minute.

It can readily be seen from these experiments that cocaine was the only one of the agents experimented with which did not interfere with the contractile power of suprarenin. The other anesthetics, such as holocaine, akoin, nirvanin, and subcutin, in combination with suprarenin, were investigated by Recke. The anesthetic power of all these substances was increased by the addition of suprarenin, but not to the same extent as when the latter substance was added to a solution of cocaine. Stovaine anesthesia is only slightly increased by the addition of suprarenin. The newer substances, alypin and novocaine, give brilliant results when combined with suprarenin. This can be readily seen by comparing the following experiments with those in the preceding chapter devoted to these drugs.

Experiment 1.—5 drops of a 1 to 1000 suprarenin solution were added to 100 cc of a 0.1 per cent solution of alypin. A wheal injected into the skin was painful. Skin did not become hyperemic. The white wheal was in the center of a white area several times the diameter of the original wheal. Anesthesia of the wheal lasted about two hours, when sensation gradually returned. Hyperemic infiltrates remained at the point of injection until the next day.

Experiment 2.—1 drop of a 1 to 1000 suprarenin solution was added to 1 cc of 0.5 per cent alypin in 0.8 per cent salt solution and injected circularly in the subcutaneous tissues of the fourth finger. The injection was painful. After about ten minutes the entire finger as far as the tip became completely anesthetic. In about two hours sensation began to return and reached the normal in about three hours. The base of the

finger remained infiltrated for several days, being red and painful. 0.5 per cent solutions of cocaine or eucaine with like addition of suprarenin did not show these latter effects.

Experiment 3.—5 drops of a 1 to 1000 suprarenin solution were added to 100 cc of a 0.1 per cent isotonic novocaine solution. A wheal was formed on the forearm; the injection was painless; anemia very pronounced. Anesthesia lasted more than an hour, disappearing without leaving any effect.

Experiment 4.—2 drops of a 1 to 1000 suprarenin solution were added to 1 cc of a 1 per cent novocaine solution. A wheal formed on the forearm. Injection painless. Anesthesia around the wheal lasted about four hours. Action of the suprarenin very pronounced. After the disappearance of the suprarenin anemia some slight pain was felt at the point of injection, but no other reaction.

Experiment 5.—0.5 cc of the same novocaine-suprarenin solution was injected subcutaneously into the forearm. The skin over the point of injection as well as the parts supplied by the nerve trunks affected by the injection were insensitive for two and a half to three hours. The action of the suprarenin was very pronounced but disappeared without leaving any reaction.

Experiment 6.—1 drop of a 1 to 1000 suprarenin solution was added to each cubic centimeter of a 0.5 per cent novocaine solution. The base of the fourth finger was circularly injected with 1 cc of this solution. In ten minutes the entire finger was both anemic and insensitive. After about ten minutes a return of sensation was noted in the tip of the finger. It required about one hour for complete return of sensation. There was no secondary pain or swelling of the finger.

From these experiments it becomes very evident that the anesthetic properties of both of these substances are enormously increased by the addition of suprarenin. This is of immense importance in the use of novocaine, as the anesthetic power of this substance without the addition of suprarenin is too fleeting to be of practical value. There is no doubt that the influence of suprarenin in increasing the local anesthetic power of this substance is similar to that produced by ligating the extremities or cooling the tissues. These changes again are brought about by a diminution of the vitality of the tissues from the suprarenin anemia associated with delay in absorption of the drug.

Klapp has graphically shown in the accompanying diagram the action of suprarenin even in very small doses upon the absorption from the tissues. He injected beneath the skin of the back of a dog 10 cc of a 6.5 per cent solution of milk sugar, examining the urine hourly for evidences of sugar. Three days later the same quantity of this solution was injected with the addition of two drops of a 1 to 1000 adrenalin solution. The urine was examined in the same manner. In Fig. 7 the hours are indicated upon the horizontal line, whereas the vertical line indicates the quantity of sugar excreted in grams. The solid line shows the excretion before the addition of adrenalin. It will be noticed that the excretion

of sugar begins immediately, reaching its maximum in about one hour, then fall slowly, stopping completely in about six hours. The entire quantity of sugar obtained in the urine was about 0.569 gm. The dotted line shows the result of the second experiment, where absorption was delayed by the addition of adrenalin. In the first hour no sugar was found in the urine, the excretion beginning only after two hours, reaching its maximum at the end of five hours, which was considerably less than in the first experiment. As long as eight hours after the injection, sugar was found in the urine, the total quantity obtained being 0.343 gm.

From these experiments it can be readily seen that the local action of a substance is increased by the use of adrenalin. Owing to delayed parenchymatous absorption it was supposed that the simultaneous use of suprarenin and cocaine would naturally diminish the toxic action of the latter drug. This is no doubt true, but the circumstances are of course

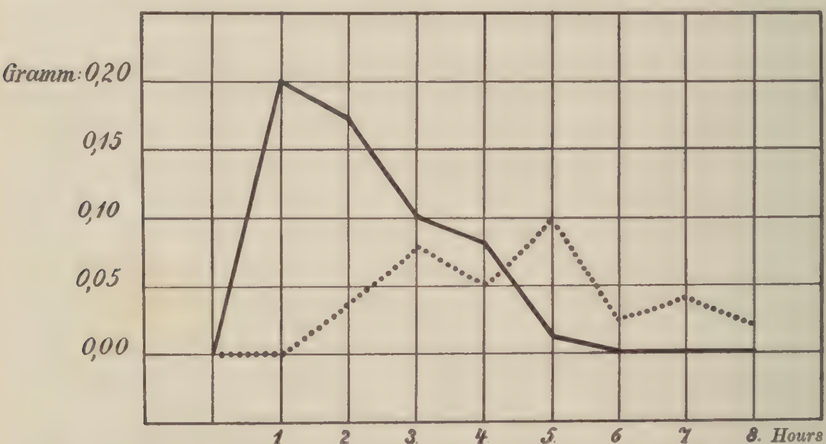


FIG. 7.—Elimination of sugar in the urine ——— without . . . . . . with suprarenin. (Klapp.)

different from those in the physical experiment. The use of cocaine introduces two toxic substances into the body, and it can possibly happen that when both are absorbed the toxicity may be increased. This is, however, not the case. Moure and Brindel have observed in rhinolaryngological practice that the toxicity of cocaine is markedly diminished by the use of suprarenin. It has also been demonstrated in suitable animal experiments that if the subcutaneous connective tissue be first injected with suprarenin and a definite time allowed to elapse for the maximum effect to take place, the toxic effect of cocaine solutions injected into the anemic tissues was not only delayed but also diminished. These observations became more apparent in the experiments conducted by Doenitz, in which he compared the action of pure cocaine solutions injected into the spinal canal of cats with that of cocaine and suprarenin. On the contrary, Thiess has found that cocaine and suprarenin when injected beneath the dura were more toxic than cocaine alone.

The site for this last experiment is unfortunately chosen, as the spinal canal is not a suitable place for determining this question, inasmuch as the action of poisons in the canal is not only due to their absorption but also their direct action upon the central nervous system. Recently, Sikemeyer in his experiments found that the central toxic action of cocaine was delayed but not diminished by suprarenin.

The fact that suprarenin delays the absorption of cocaine solution which has been injected is indisputable. Likewise the fact that cocaine introduced slowly into the circulation is less toxic than when rapidly absorbed. This shows that suprarenin has a direct effect upon the toxic action of cocaine under suitable experimental conditions. The practical value of the addition of suprarenin to cocaine solutions does not lie in the fact that larger doses of cocaine can be used, but that dilute solutions of the anesthetic substance can produce a more intense reaction of longer duration with the addition than without.

The value of suprarenin solution in local anesthesia is dependent alone upon its vasoconstrictor properties with the consequent anemia of the tissues. The remarkable increase of the local anesthetic power of a substance due to suprarenin is similar to that due to the ligation of extremities. Esch has found that in animals in which the circulation has been interrupted the action of suprarenin causes a marked increase in the local action of cocaine, alypin, and novocaine, and he compares these results, which are in nowise dependent upon the anesthetic property of suprarenin, with the mordant used in dyeing. Schoff came to a similar conclusion.

Animal experimentation has demonstrated, just as we have observed before with cocaine, that the toxic action of suprarenin when introduced intravenously into the unobstructed circulation is enormously increased over that introduced subcutaneously, as in the latter method absorption is hindered and a portion of the substance is not absorbed at all. According to Batelli, Taramasio, Bouchard, and Claude, 0.0001 to 0.0002 of suprarenin per kilo when introduced intravenously into rabbits or guinea-pigs causes death, whereas the fatal dose for subcutaneous injection is more variable, being between 0.002 and 0.02 per kilo, the fatal dose for guinea-pigs being 0.01 cc and for rabbits 0.02 per kilo. Batelli states that the intravenous injection of suprarenin is about forty times more toxic than that introduced subcutaneously. The reason for the lessened toxicity of this substance in subcutaneous injection is readily understood if the delay of absorption due to the local action of this substance is taken into account.

Toxic symptoms following the injection of suprarenin in animals are evidenced by paralysis of the extremities with tonic and clonic convulsions, opisthotonos, and mydriasis, frequent respiration, edema of the lungs, anemia of the viscera, and glycosuria. By means of repeated intravenous injections of small doses of suprarenin, Josué, Loeper, Erb, and Kuelbs were able to produce in animals calcification of the aorta, coronary vessels and the heart.

The first experiments for the determination of the dosage to be injected

subcutaneously were made by the author in 1902. He injected under the skin of the forearm 1 to 1000 solution of suprarenin in increasing doses. After the injection of 0.5 mg. (=0.5 cc) general symptoms occurred. Five minutes after the injection he experienced a sense of oppression in the chest. It became necessary to breathe more rapidly and deeply. Palpitation followed, the pulse increasing from 64 to 94 per minute. At this point it was necessary to lie down. The symptoms disappeared completely in one and a half minutes; glycosuria did not occur. When the solution of adrenalin was diluted ten times with salt solution, 1 mg. could be injected without noting any symptoms. Doenitz made similar observations upon himself, being able to inject 1.5 mg. of adrenalin in 1 to 1000 solution before symptoms were observed. Thiess injected into two persons with healthy circulatory systems 1 mg. of adrenalin in a 1 to 2000 solution, in another case 0.2 mg. in a 1 to 10,000 solution, and noted that the blood-pressure was increased 15 to 45 mm. of mercury. This occurred a few minutes after the injection and lasted three to eight minutes. No other general symptoms were observed. The experiences of recent years have proved that the dose of suprarenin when used for local anesthesia is of apparently no consequence. Inasmuch as the dose is so small and is injected in such dilute solution (1 to 100,000 to 1 to 200,000), general symptoms from this substance could not be expected. Physicians use suprarenin in combating symptoms of collapse in infectious diseases. The quantity used subcutaneously is as follows: Liebermeister and Kauer give 1 to 6 mg. daily; Kraus 6 mg. daily, in divided doses of 0.5 to 1 mg. Eckert gives 2 to 3 mg. every three or four hours. Kirchheim from his experiments claims that suprarenin is a perfectly harmless drug if given 1 mg. hourly or every four hours. In severe collapse 2 or 3 mg. at one dose; 24 mg. have been given in twenty-four hours--60 to 400 mg. of suprarenin in a 1 to 1000 solution being given in all. The quantity used in dilute solutions for local anesthesia must necessarily be harmless, provided only clean, active preparations of the fresh solution be used.

An unknown writer reported in the *Zentralblatt f. Gynäkologie,*[1] under the title "Warnung vor Adrenalin," that in 1908 he experienced two sudden deaths from syncope in women at the beginning of chloroform anesthesia following the injection of 0.0003 adrenalin in a 1 to 10,000 solution into the portio vaginalis for the purpose of preventing hemorrhage. These cases were critically investigated by Fisch,[2] Neu, Freund,[3] and the author. They were declared to be typical chloroform deaths.

The concentration of suprarenin in anesthetic solutions is of much importance, as the intensity of the local action of suprarenin and the duration of the anemia of the tissues is dependent upon its concentration. Suprarenin is not a definitive hemostatic. For this reason the concentration of suprarenin solutions should never be sufficient to cause a complete cessation of bleeding, such as occurs with the use of the Esmarch bandage. The medium-sized arteries must be permitted to bleed so that

[1] 1909, p. 67. [2] Ebenda, p. 1277. [3] Ebenda, p. 1079.

they can be ligated, and hemostasis even of the smallest bleeding-point must be secured by ligature, tampon, or a compression bandage, so that all possibility of secondary hemorrhage can be avoided. The care of wounds following this injection must be similar to that following use of the Esmarch band. If the action of suprarenin be too intense or long continued, gangrene of the tissues can occur, particularly if the nutrition of the part is already interfered with, as, for instance, in arteriosclerosis of the extremities, wounds, or plastic flaps. Siebert has collected cases of this kind. It should be the rule not to inject into tissues in which the vitality is already reduced, inasmuch as they recover very slowly, if at all, from the effect of this agent. In plastic flaps it is important to remember that no anesthetic should be injected into the flap, at least not into parts remote from their nourishing pedicle.

With the observance of these rules and those to be mentioned in the later chapters of this book in reference to the special directions regarding the dosage and use of novocaine-suprarenin solution, no serious consequences need be feared. The limits of usefulness of local anesthesia have been materially increased since the introduction of suprarenin. Its results are more certain, the technic in many instances had been simplified, and danger from certain operations has been markedly reduced.

CHAPTER IX.

THE VARIOUS METHODS OF USING LOCAL ANESTHETIC DRUGS.

1. ANESTHESIA OF SUPERFICIAL SURFACES, AS MUCOUS, SEROUS, AND SYNOVIAL MEMBRANES, AND WOUNDS.

The first practical use of cocaine anesthesia as made by Köller consisted in the instillation of cocaine solutions into the eye for the purpose of making the conjunctiva insensitive. All other mucous membranes were found susceptible in the same manner to cocainization. The mucosa of the bladder which, as is well known, is impenetrable to some substances, can be anesthetized. The anesthesia is not dependent upon the power of absorption of this membrane, which usually plays a passive role, but upon the fact that small quantities of the anesthetic solution when placed upon its surface diffuse through the epithelium and in this way come in contact with the nerve-endings in the submucous layers. The anesthesia, as a rule, does not extend beyond the submucosa. The application of cocaine solutions is made by painting the surface, by means of cotton tampons saturated with the solution, by using fine sprays, by instillations into the eye, and by injections into the urethra and bladder.

The necessary concentration for suitable anesthesia depends upon the manner in which the solution can be applied to the mucous membrane. If the parts are anesthetized by painting, the application of tampons, or by means of the spray, very concentrated solutions (10 to 20 per cent) will be necessary if it is expected to obtain a rapid anesthesia and one of sufficient duration. Instillations into the eye and injections into the urethra can be made with much weaker solutions, as the contact between the mucous membrane and the anesthetic is much more prolonged.

Anesthesia of the bladder can be made just as satisfactorily with weak solutions as with the more concentrated if the former are allowed to remain in contact with the surface for a sufficient length of time.

Attention has already been directed to the fact that, to avoid cocaine poisoning, no definite rules for dosage can be laid down, but the extent of surface and power of absorption of certain areas must be taken into consideration in determining the concentration of the solution to be used. Concentrated solutions should never be applied to large mucous surfaces; their use should be limited to circumscribed areas.

The use of suprarenin is of much value in anesthesia of the mucous membranes. It is possible with this addition to avoid the use of highly concentrated cocaine solutions with their secondary effects, which previously were indispensable in laryngology, rhinology, and urology. Swain,

and later Burkofzer, who were the first to introduce this agent in the practice of laryngology, directed attention to this valuable property of suprarenin, which they termed "Kokainsparer." According to Moure and Brindel a 3.5 per cent cocaine solution with the addition of suprarenin is sufficient for anesthesia of the larynx and nasal mucous membrane. Burkofzer and Rode stated that a 5 per cent solution with the addition of suprarenin should be used. However, with either of these solutions an anesthesia of such intensity and duration will be obtained as has never previously been known. The substitution of other substances for cocaine are discussed on pages 123 to 127. Regarding the chilling of mucous membranes as an aid to local anesthesia and the use of the ethyl chloride solutions containing basic cocaine, see pages 92 and 129.

The local action of cocaine when applied to other permeable membranes is similar to its action on mucous membranes. The peritoneum, the peritoneal covering of hernial sacs, and the tunica vaginalis can be made insensitive, the first by applying anesthetic solutions to the surface after opening the abdomen (Schleich recommends tropacocaine in substance for this purpose). The latter can be anesthetized by injecting a quantity of the anesthetic solution into the scrotal sac. The use of cocaine for this purpose is not necessary and should be avoided. If the scrotal sac is filled with a 0.5 to 1 per cent novocaine-suprarenin solution the tunica will rapidly become insensitive.

Joint cavities can readily be made insensitive by injecting into them anesthetic solutions (Reclus, Lorenz, and von Hacker). This can be practically applied in the aspiration and washing of joint cavities in hydrarthrosis for the injection of iodine and iodoform in tuberculosis of the joints. Lorenz was able to forcibly correct a flat foot after injecting an anesthetic solution into the tarsocrural joint. We will later study anesthesia of the synovial membranes by injection into the joints as a means of making them insensitive for operation. Conway and Quénu have shown how readily a dislocated joint can be reduced following the intra-articular injection of anesthetic solutions.

Fresh, granulating wound surfaces and freely exposed nerve trunks can be anesthetized by the superficial application of an anesthetic agent. In the first case orthoform or some of the newer preparations—anesthesin, zycloform, or propäsin—can be used [but not for operative anesthesia.—Ed.]

2. ELECTRIC CATAPHORESIS AS AN AID TO LOCAL ANESTHESIA.

The unbroken human skin is impenetrable to most substances in watery solutions. Drugs dissolved in alcohol, ether, or chloroform have slightly better powers of penetration (Parisot). Munk observed that drugs could be introduced into the system by means of the galvanic current. The positive electrode, saturated with a strychnine solution, applied to a rabbit causes death from strychnine poisoning in about five minutes. Potassium iodide and quinine have been introduced in man by this means. This method, known for some time under the name of cataphoresis, was tried

in local anesthesia by Wagner and Herzog. Wagner placed the anode saturated with a cocaine solution upon the skin and found that the latter became insensitive in a few minutes, the intensity of this action depending upon the concentration of the cocaine solution and the strength of the current, which was always in inverse propertion to the diameter of the electrode.

With an electrode 2.5 cm. in diameter, a 5 per cent cocaine solution and a current of 5 ma., it required four to five minutes before the skin became anesthetic. By interrupting the circulation in an extremity on which the experiments were being made, the duration of the anesthesia could be materially prolonged. Similar results were obtained by Herzog, Corning, and Peterson. This anesthesia was limited to the cutis and did not affect the deeper lying parts such as nerve trunks (Herzog). Corning was able to produce a deeper anesthesia by first abrading the skin with an instrument. Electrodes devised by Adamkiewicz, Stinzing, and Peterson are particularly suitable for cataphoresis and the testing of the anesthetic solutions. The electrode devised by Adamkiewicz is faulty or, as Peterson has stated, "constructed with inexcusable stupidity," inasmuch as the electric current does not pass through the fluid. The author conducted a number of experiments with cocaine-suprarenin solutions but has not been able to determine that the method was of sufficient value to warrant its more extensive use. He has also attempted to produce a deeper anesthesia by means of the galvanic current applied to solutions of cocaine injected subcutaneously. It can, therefore, be said that the practical application of cocaine cataphoresis is of very little value. Corning and Peterson used this method in cases of hyperesthesia and neuralgia; Harries used it for ignipuncture. More recent investigations by Peterson have shown that minor operations can be carried out without pain by the use of a 10 to 20 per cent cocaine solution applied with the anode. Cataphoric applications of cocaine solutions and cocaine-guaiacol solutions have been used for some time in dentistry for the purpose of making dentine and extraction painless. The results of this procedure, notwithstanding the praise given it by many operators, have not been very brilliant (see monograph of Dorn). More recently Albrecht has used cocaine cataphoresis with apparent success for anesthesia of the ear-drum.

3. INFILTRATION ANESTHESIA.

Infiltration anesthesia is a form of terminal anesthesia brought about by saturating the tissues with anesthetic solutions. By the use of suitable drugs the nerve elements lying in the infiltrated tissues become functionless. If the injected solutions contain large quantities of the anesthetic, the anesthesia extends by diffusion for some distance beyond the infiltrated area. This secondary anesthesia is known as indirect infiltration anesthesia (see page 70). The action of the anesthetic is always due to its contact with the sensory nerve elements. The term "infiltration anesthesia" originated with Schleich; the method, however,

as described by him differed from the older methods only in the use of more dilute cocaine solutions.

Solutions of cocaine were used originally almost entirely for infiltration anesthesia in the form of so-called indirect infiltration anesthesia. Small quantities of a concentrated cocaine solution were injected into the tissues at definitely spaced points and then one waited, using the Esmarch bandage in case of necessity, until the entire field of operation was made anesthetic. It has been previously mentioned on page 73, that shortly after the introduction of cocaine, many surgeons held that it was necessary to completely infiltrate the tissues with cocaine solution if a reliable result was to be obtained. Roberts, in 1885, and later Reclus and Schleich, used infiltration of the skin in the form of a series of skin wheals in the entire proposed line of incision. The advancement in technical detail of infiltration anesthesia is due to Reclus and Schleich; their methods, at least in principle, cannot be separated from one another. The technic of Reclus and his pupils, Auber, Fillion, Legrand, Kendirdjy, and Piquand, have been known since their numerous experiments in 1889. This technic, in short, consisted in making injections into the skin with cocaine solutions throughout the entire extent of the incision and infiltrating in a similar manner all tissue layers to be cut. Reclus in 1893 used a 1 per cent cocaine solution for injection, later reducing this to 0.5 per cent. He did not depend upon the diffusion of the cocaine solution, relying only upon direct infiltration. Reclus, from the very beginning of his method, did not confine its use to minor surgery but recommended it for various major operations, such as herniotomies, resection of the ribs, and many others.

According to his experience in more than 7000 cases the method was apparently without danger, provided the rules already mentioned on page 89 were observed, a dose of 0.2 not being feared. Ceci, who used a 0.5 per cent cocaine solution for infiltrating the skin, found anemia of the brain and psychical excitation in only a few cases out of 4054, no other symptoms of cocaine poisoning were observed. For these reasons we cannot agree with the statement of Schleich that the danger from cocaine anesthesia, used according to rule, is greater than that of chloroform anesthesia. The infiltration method of Reclus was little known in Germany and was not used to any great extent owing to the fact that for extensive operations comparatively large doses of cocaine were necessary, and because Schleich had shown that more extensive anesthesia of the tissues could be obtained than heretofore by the use of very dilute solutions. It requires some little thought to separate this simple and important fact, to which we are indebted to Schleich, from numerous hypothetical embellishments suggested by this author. Schleich, about 1891, reported 224 operations, including herniotomies and laparotomies, performed with a 0.2 per cent cocaine solution in combination with the ether spray, a dosage of 0.04 cocaine not being exceeded. He claimed that the cooling of the skin was only of importance in preventing pain from the insertion of the needle. We now know that cooling by means of the ether spray

produces a marked increase in the action of cocaine. In the monograph by Schleich, which appeared in 1894, the use of ether or ethyl chloride sprays was considered an essential part of infiltration anesthesia.

Schleich used 3 different cocaine solutions for infiltrating the tissues:

No. 1.

Cocaini muriat	0.2
Natri chlorati	0.2
Morphini muriat	0.02
Aquæ dest.	100.0

No. 2.

Cocaini muriat.	0.1
Natri chlorati	0.2
Morphini muriat	0.02
Aquæ dest.	100.0

No. 3.

Cocaini muriat	0.01
Natri chlorati	0.2
Morphini muriat	0.005
Aquæ dest.	100.0

The No. 2 solution, containing 0.1 of cocaine, was the one most frequently used (95 per cent of all cases). Solution No. 1 was used for anesthetizing inflamed hyperemic tissues. Solution No. 3, containing 0.01 of cocaine, was only used when the maximum dose had nearly been reached with the other solutions, also for the infiltration of less sensitive nerves and tissues. According to Schleich it was very rarely necessary to use a 0.5 per cent cocaine solution for infiltration of hyperesthetic areas. The above-mentioned solutions were prepared by Schleich from the following observations. He found in testing skin wheals that water with the addition of 0.2 per cent salt caused anesthesia in the infiltrated tissues, whereas a 0.75 per cent salt solution left sensation intact. He also observed that the action of very weak cocaine solutions was much more complete when this agent was dissolved in water or in a 0.2 per cent salt solution than when physiological salt solution was used as a solvent. Because pure water produced a severe irritation upon injection he added 0.2 per cent of salt to his solutions. In regard to the solutions which Schleich has termed "indifferent solutions," he has drawn the following conclusions: "Anesthesia is spread by means of the solution, it being a purely physical process, the chemical factors only coming in for consideration in relieving the pain of injection. Watery solutions above all others produce the best anesthesia."

Artificial edema itself acts as an anesthetic by causing pressure on the nerve substance, anemia of the tissues, and a difference in temperature between the body and the solution. (Schleich recommended the use of cold cocaine solutions for injection.) In this connection Schleich himself observed that the infiltration of the tissues with physiological salt solution did not alter sensation. Heinze and the author infiltrated their own tissues to the point of distention with an indifferent isosmotic 0.9 per cent salt solution, both warm and cold, without obtaining a diminution

of sensation but frequently a hyperesthesia. It can therefore be said that the artificial edema of the tissues not only does not produce anesthesia, but usually increases the excitability of the nerves. The forcible injection in a circumscribed area of solutions at about 0 degree temperature can produce a local anesthetic effect by causing a local anemia and a diminution in the vitality of the tissues. This has already been referred to in Chapter VIII, in which the increased action of anesthetic solutions injected as just described was fully discussed. It appears very doubtful to the author's mind whether this method is of any great value; at any rate the action of the injections upon the tissues is not a physical one. The only physical effect to be noted in connection with the injection of Schleich's solution is a diminished sensation due to tissue swelling, the solution causing a certain degree of tumefaction anesthesia (see page 60). The intensity of the anesthesia depends upon the freezing-point of the solution. The freezing-point of solution No. 1 is —0.156°, No. 2 is —0.145°, and the third solution is similar to a 0.2 per cent salt solution, being —0.13°. In Fig. 4, page 57, the solutions are placed in their relative position on the curve. The injection of 0.2 per cent salt solution into the cutis not only produces paresthesia, as suggested by Schleich, but the severe pain of tumefaction. This can be avoided by the addition of 0.04 per cent of cocaine, but not by solution No. 3, containing 0.01 per cent of cocaine.

These secondary effects must be less when using solutions Nos. 1 and 2, as their freezing-point, in consequence of the addition and morphine, are quite different from that of pure water. In contrast to the marked anesthetic power of a 0.1 per cent and 0.2 per cent cocaine solution, the physical secondary effects are of the smallest practical importance, and it would be a most uncertain state of affairs if we were to attribute the anesthesia of the Schleich solution to its physical effects, and the Reclus infiltration anesthesia to the effect of cocaine. All these solutions produce anesthesia owing to their cocaine content, and the author has been able to determine experimentally that there is no difference in the anesthetic power of cocaine, even as dilute as 0.02 per cent, whether dissolved in a 0.2 per cent or in a 0.8 per cent salt solution. Heinze and Legrand have not been able to determine the slightest difference in the anesthetic property of a No. 2 Schleich in a watery solution or 0.8 per cent salt solution. The cocaine anesthesia is so marked in the experiments as to interfere with the observance of any perceptible tumefaction anesthesia, and it is only when solutions fo cocaine are very dilute that it can be noticed. In watery cocaine solutions of 0.01 per cent, cocaine anesthesia cannot be noticed, the solution acting as a pronounced irritant and showing anesthetic properties similar to that of pure water. Solutions of 0.01 per cent cocaine in 0.8 per cent salt solution produce a slight cocaine anesthesia of short duration without irritation; solutions of 0.01 per cent cocaine in 0.2 per cent salt solution or Schleich solution No. 3 show a slightly more intense anesthetic action. In the latter we see a combination of cocaine and tumefaction anesthesia. The injection is painful and the cocaine anesthesia cannot prevent the pain of tumefaction.

Schleich's physical hypothesis is dependent upon this practical but unimportant difference which can only be determined by the most experienced observer. Watery solutions having a freezing-point similar to 0.2 per cent salt solution cause a destruction of red- and white-blood corpuscles, and their injection into the tissues may cause a tumefaction necrosis. For this reason it is advisable only to use injections which have been made indifferent by the addition of 0.8 to 0.9 per cent salt. In this way the desired anesthesia can be obtained without the practically unimportant physical effects of the Schleich solution. The use of salt solution for injections into the tissues will therefore exclude the physical and limit the anesthesia to the specific action of cocaine.

In 1898 the author clearly stated that the addition of morphine to the local anesthetic was not of the slightest value in Schleich's solution, which statement has been verified by Heinze, Custer, and Gradenwitz. The diminution of after-pains, which Schleich attributes to the addition of morphine, can only be of central origin and are not due to any local effect of this substance. For this reason it is better to inject the morphine, if it is considered necessary, in another part of the body rather than immediately into the operative field; or it may be administered before operation, as has been recommended by many surgeons, so as to increase the duration and intensity of the local anesthetic or diminish the after-pains.

The use of 0.01 to 0.1 per cent cocaine in 0.8 per cent salt solution, the object of the latter being to prevent swelling of the tissues, acts in exactly the same manner as the Schleich solution with morphine. Hackenbruch, Gottstein, Legrand and others have recommended mixtures of eucaine and cocaine for the purpose of utilizing the less toxic effect of eucaine and at the same time retaining the effect of cocaine in contraction of the blood-vessels. Schleich also used mixtures of cocaine and alypin. In reference to the other substitutes for cocaine up to the time of the introduction of novocaine, see the previous chapter.

The saturation of the tissues with anesthetic solutions is carried out in layers, according to the recommendation of Reclus and Schleich, and is made from without. The anesthesia is begun by the injection of successive wheals throughout the entire length of the proposed incision (see Chapter X), then just before cutting the skin the subcutaneous connective tissue is injected in the same direction. When using a 0.5 to 1 per cent cocaine solution, it should be given as sparingly as possible. When using the Schleich solution, the anesthetic zone is injected from two wheals at the ends of the proposed incision, and the subcutaneous connective tissue so saturated that the field of operation is raised above the surrounding surface of the skin like a tumor or swelling. The skin and subcutaneous connective tissue can now be cut without pain. In some cases Schleich infiltrates for some distance beyond the subcutaneous connective tissue before beginning the operation. After infiltrating the subcutaneous connective tissue according to the method of Schleich the parts become edematous and the injected fluid flows in part from the cut

surface. After incising the tissues, as above mentioned, the other layers are successively injected before cutting, using small quantities of 0.5 to 1 per cent cocaine solution or larger quantities of the dilute Schleich solution. Nerve trunks crossing the field of operation, particularly when using the Schleich solution, must be anesthetized in a manner which will be described later. The periosteum, according to Schleich, becomes rapidly insensitive if the subperiosteal tissue be infiltrated with dilute cocaine solutions and can then be cut or separated from the bone. Periosteal injections are difficult and often impossible.

Bone can be cut without pain if the subperiosteal infiltration has been carefully performed and made sufficiently extensive. This does not apply to bones with sensory nerve trunks, like the upper and lower jaw, as these nerves retain their sensation following the use of the Schleich solution. Direct mechanical infiltration of bone is impossible. Dzierzawsky has demonstrated that colored solutions injected beneath the periosteum penetrate the bone. This is certainly not due to mechanical infiltration but rather to a process of diffusion. To produce anesthesia of the nerve elements in the bone it is necessary to use highly concentrated cocaine solutions for injection beneath the periosteum. Dilute cocaine solutions cause just as little effect in their distal action on bone as dilute color solutions. Mucous membranes are rendered insensitive by infiltration of the submucous connective tissue. In order to remove a tumor from the submucous tissues all of the surrounding tissue bordering the tumor must be made insensitive, or, as Reclus states, it must be surrounded by an atmosphere of cocaine. According to Schleich, the skin over the entire extent of the proposed incision, be it straight, curved, or oval, must be infiltrated, also the tissues on all sides of the tumor, by using curved needles, so that all of the tissues become filled with dilute cocaine solutions. Schleich anesthetizes the parts for opening an abscess or furuncle by first infiltrating the tissues, such as subcutaneous connective tissue, fascia, and muscles which are not inflamed but surround the inflammatory area, and last of all before incising the abscess the inflamed tissues themselves are infiltrated. The use of solutions very near the lowest border of activity of cocaine has been advocated by surgeons universally for infiltration anesthesia and the way has been opened for the use of such solutions in abdominal operations.

These dilute solutions for infiltrating the tissues, according to Schleich, have their advantages and disadvantages over the method of Reclus. The advantage consists in the fact that much less cocaine is used; the disadvantage being that the tissues are not rendered perfectly insensitive and the duration of the anesthesia is quite short, so that in operations of some length the skin becomes sensitive before their conclusion and must again be infiltrated.

The endeavor to anesthetize areas with very dilute solutions must be considered an advantage, but this infiltration, according to the method of Schleich, is not always possible and does not always produce complete anesthesia in the field of operation, many of the sensory tracts retaining

their sensation. If the skin and subcutaneous connective tissue are cut immediately after infiltration with a 0.1 per cent cocaine or eucaine solution, even though the tissues are swollen and edematous, the parts are not always completely anesthetic. Closer investigation will show that the nerves accompanying the bloodvessels in the thicker layers of the tissue remain painful to cutting, pressing, pulling, or grasping with instruments. This pain is described as slight by some patients, whereas others complain very bitterly. It is a mistake to draw conclusions from experiments on the skin, as other tissues, such as subcutaneous connective tissue, do not possess sensation but serve merely the purpose of transmitting the sensory nerve trunks. It is impossible to infiltrate all the tissues equally by injections into the subcutaneous connective tissue as can be done in the skin. The injected fluid follows the course of least resistance, filling the spaces between the tissues and penetrating the connective tissue containing bloodvessels and nerves just as little as it does the fascia and skin. It is only under pathological conditions of inflammation and chronic infiltration, where the skin and subcutaneous connective tissue assume a more or less similar consistency, that these parts can be infiltrated by injections into the subcutaneous connective tissue. After cutting the tissues the painful points can be touched with a 5 per cent carbolic acid solution (Schleich), or again infiltrated with the anesthetic solution, but this, of course, should only be done if the patient has given expression of pain. Only the larger nerve trunks in the operative field, the position of which is determined from our anatomical knowledge, must be sought and properly treated. The muscles act similarly to the subcutaneous connective tissue, for which reason an even infiltration with fluid is impossible. The solution is forced between the muscle fibers but does not penetrate the thick connective-tissue septa containing the bloodvessels and nerves. The cutting of muscles immediately after infiltration with very dilute cocaine solutions is frequently painful. Von Friedländer, who has always expressed much enthusiasm for the infiltration of Schleich, stated that it was never possible for him to make a muscle insensitive throughout its entire cross-section.

The action of anesthetic solutions on nerve trunks passing through tissues which have been infiltrated can be explained by the writer's experiments upon the fingers. If the subcutaneous tissues at the base of a finger are infiltrated circularly, the sensory nerves will lose their conductivity as soon as the entire finger becomes insensitive. If this does not occur, the infiltrated subcutaneous connective tissue has not been made insensitive. It has been shown that the action of a 0.1 to 0.2 per cent cocaine solution is so slight that larger nerve trunks frequently are not made insensitive. It also requires considerable time before a nerve trunk passing through infiltrated tissues becomes insensitive. These conditions can be changed by increasing the concentration of the anesthetic solutions or by the use of a ligature around the extremity. The addition of suprarenin or chilling the parts renders anesthetic action much more rapid and interrupts the sensory tracts with much more certainty. The

conductivity of nerves is never immediately interrupted, even with the use of 0.5 to 1 per cent cocaine solutions, with the addition of suprarenin or ligation of the extremity; so if the skin of the finger and its subcutaneous connective tissue have been infiltrated with 0.1 per cent cocaine solution and incised immediately, the sensation of the subcutaneous connective tissue will still be present. For these reasons the usefulness of Schleich solution containing 0.01 per cent of cocaine for infiltrating tissues containing nerve tracts is highly problematical. Tissues which become anesthetic following injections with these dilute solutions in all probability would not have required infiltration at all. In parts of the body which contain only the sensory nerve endings and no nerve trunks, as, for instance, in the median line of the abdomen and neck, the dilute solutions of Schleich are very satisfactory; but if the tissues injected contain larger nerve trunks, it is a very uncertain and difficult procedure for each one of these nerves must be sought and injected separately in order to anesthetize them.

These disadvantages may be partially overcome by the observance of certain rules, the first and most important of which is to wait after infiltration until anesthesia occurs. It is a mistake to attempt to cut tissues immediately after infiltration, as all tissues do not become immediately anesthetic, as we have observed. No matter where one injects, the action of the anesthetic requires time, and its maximum efficiency will only be attained after many minutes have passed. This circumstance as to time was not considered by either Reclus or Schleich in their technic. If the tissue layers are successively infiltrated, first infiltrating and then cutting, it is necessarily impossible to wait the requisite time for the action of the anesthetic; therefore, it is desirable to methodically infiltrate the tissue layers before beginning the operation, starting with the deepest and finishing with the most superficial layer, so that further injections during the operation will be rendered unnecessary (see Chapter IX). If this rule is followed, it will be seen that a separate infiltration, as, for instance, in the skin and periosteum, will never be necessary. It is also much better in most cases not to infiltrate the line of incision itself but the area surrounding the operative field which contains the nerves innervating the parts to be cut. The second rule is to use such substances as will cause a delay in the parenchymatous absorption of the local anesthesia. This is a preliminary measure which is very necessary for the success of the technic here described, and yields not simply anesthetized lines for small incisions but extensive fields for operations and avoids the inadmissible infiltration of diseased tissue.

CONDUCTION ANESTHESIA.

The ability of cocaine to interrupt the sensory and motor nerve trunks was demonstrated by Torsellini, Feinberg, Alms, Kochs, Witzel, Mosso, and Frank. The first observations of this kind made on man originated with Corning and Goldscheider, but were only of theoretical interest. After

ligating the upper arm Corning injected into the trunk of the nervus cutaneus antebrachii lateralis 0.3 cc of a 4 per cent cocaine solution and immediately noticed anesthesia of the skin supplied by this nerve as far as the wrist. Goldscheider, without interrupting the circulation, was able to obtain anesthesia in the area of distribution of a nerve following the subcutaneous injection of strong solutions of cocaine.

Anesthetic solutions can be used in various ways for anesthetizing nerve trunks. The injection can be made immediately beneath the fibrous sheath directly into the nerve trunk (endoneural injection). If injected solution is not too weak, almost immediate interruption of conductivity occurs (Crile). This procedure is only possible when the nerve trunk has been freely exposed before operation. Very few nerve trunks are so situated that they can be reached exactly with the needle through the unbroken skin. As a rule, it is only possible to inject the solutions in the neighborhood of the nerve trunks (perineural injections). The interruption of conduction by this procedure requires some little time, inasmuch as the nerve trunk is reached only by diffusion. Conduction anesthesia can also be produced by direct injections into the spinal canal, according to the method of Bier, or by injections into the epidural space of the sacrum, according to the method of Cathelin-Laewen. Intravenous and intra-arterial injections produce anesthesia not only by their action on the nerve ends but also on the nerve trunks.

Perineural Injections of Anesthetic Solutions.—The action of anesthetic solutions upon nerve trunks passing through tissues infiltrated with anesthetic solutions is indirect. The anesthetic must diffuse through the connective tissue layers surrounding the nerve trunks before the nerve substance is anesthetized. For these reasons it will be observed that sensory nerve tracts are much more readily and more quickly interrupted when the perineural injection is made in the area where the nerve branches are very thin rather than in the neighborhood of the beginning of the nerve trunk, for instance, in the neighborhood of the spinal cord, where it will be found that much larger quantities of a more highly concentrated solution will be necessary for the interruption. This is due to the fact that the nerve trunk not only increases in thickness toward its proximal end, but the thickness of its connective-tissue covering is also increased. It will be noticed that the action of an anesthetic in the spinal canal is very prompt and pronounced, owing to the fact that the nerve trunks are not protected by this connective tissue covering. The interruption of nerve trunks by means of perineural injections is for the purpose of rendering their areas of distribution insensitive and is by far the most important procedure in local anesthesia. Every infiltration of connective-tissue layers containing nerve tracts produces not only infiltration anesthesia in the area injected, but also conduction anesthesia in the area of distribution of the nerves affected.

The simplest form of conduction anesthesia follows the injection of anesthetic solutions into the subcutaneous connective tissue. Inasmuch as the subcutaneous connective tissue contains the sensory nerve tracts

for the overlying skin, this structure must of necessity be made insensitive, when the subcutaneous connective tissue is infiltrated with an anesthetic solution. It might be thought that the anesthesia of the skin is produced by diffusion of the injected anesthetic from the subcutaneous connective tissue; but this is probably not the case, as the small quantities of solution which would reach the skin in this way would make the parts less insensitive than a direct infiltration of the skin with the same solution. On the contrary, it will be noted that solutions injected into the subcutaneous connective tissues produce an anesthesia of the same intensity and duration as that following the intracutaneous infiltration of the same solution; in fact, this effect is produced beyond all doubt by interrupting the nerves supplying the skin. The innervation of the periosteum takes place not from the bone but from the tissues overlying it; therefore, if these tissues be infiltrated, both periosteum and bone will be made insensitive and subperiosteal injections will be found as unnecessary as the direct infiltration of the skin.

Hackenbruch has described the so-called "circular analgesia," which consists in so circumscribing the operative field with the anesthetic solution that all nerve supply to this part will be interrupted. Hackenbruch used for this purpose 0.25 to 0.5 per cent cocaine and eucaine solutions, but the addition of the newer aids to local anesthesia were necessary for progress with this procedure. Until the introduction of these substances his method of anesthesia was only applicable to the ligated extremities. Oberst used a similar method for anesthetizing the fingers and toes. If 0.5 to 1 per cent cocaine solution is injected beneath the skin of the base of the finger or toe which has been ligated, a complete transverse anesthesia of the entire finger or toe will follow in a few minutes. The infiltrated subcutaneous connective tissue of the finger contains many nerve tracts; the finer branches supplying the skin are rendered non-conductive; the larger branches supplying the other parts are affected by diffusion. The anesthesia proceeds in this way from the center toward the periphery, the disappearance of sensation in the finger tip indicating that all nerve trunks in the subcutaneous connective tissue supplying the finger have been interrupted. In an operation upon a finger anesthetized in this manner all nerve trunks are found insensitive. A transverse incision can be made in any segment of the finger without pain. This method was used in 1888 by Oberst, but was first described in 1890 by Pernice. It is possible that Kummer and others may have preceded these writers, but it was not until the author's reference to this subject in 1897, in connection with a similar report by Hackenbruch, that this method came into general use. The first practical application of the perineural injection of cocaine for the purpose of blocking various nerve trunks at a distance from the operative field was performed by Hall and Halstedt. The first mentioned injected cocaine into the infraorbital nerve; the latter into the trunk of the inferior alveolar nerve for the purpose of extracting teeth without pain.

The ligation of an extremity is not absolutely essential for the anes-

thesia of nerve trunks, as has been shown in the reports of Krogius in 1894; but if this is not done, more highly concentrated cocaine solutions will be necessary. In reference to this anesthesia Krogius reports as follows: If one injects beneath the skin of the dorsum or palmar surface of the hand or the foot transverse lines of a 2 per cent cocaine solution, the parts distal to this injection will become anesthetic, and if the four nerves supplying the fingers be anesthetized by the injection of 1 to 1.5 cc of a 2 per cent cocaine solution, the fingers will become totally anesthetic in about ten minutes. It is possible to produce an analgesia of the ulnar side of the hand as far as the base of the fourth or fifth finger by means of an injection over the ulnar nerve where it passes through the groove on the inner condyle of the humerus. If an injection is made in the neighborhood of the supraorbital foramina, analgesia of the entire mid-portion of the forehead will occur. Injections around the base of the penis will render the foreskin entirely insensitive. This method is of little practical use for operations upon the arms or legs and has not been of any value in operations in the gluteal region. This analgesia reaches its maximum intensity and extent after from five to ten minutes and continues for a quarter of an hour or longer. The effect of the cocaine is much more satisfactory if an Esmarch band is placed above the area injected. The above statements express the experiments of Krogius. The fact is, however, the ligation is not necessary if 0.02 cocaine in 1 to 2 per cent solution be injected into a finger in the method described, anesthesia occurring in the course of a few minutes without interrupting the circulation; but the use of the various aids to local anesthesia permit of a diminution in the dose of cocaine and the concentration of its solutions and should be recommended as making action more certain and prolonging the duration of the anesthesia. A 0.1 to 0.2 per cent cocaine solution injected circularly beneath the skin of the basal phalanx of a finger will cause a complete break in the conductivity of the nerves. It is, however, necessary to wait considerably longer for this to occur than after the use of more concentrated solutions.

The above-mentioned communications of the author have been the means of stimulating much experimental work along these lines by such men as Honigmann, Manz, Arendt, Sudeck, Berndt, Gerhardt, Hoelscher, and Luxenburger. They have used the method of Oberst for operations upon the fingers and toes and have attempted to increase the extent of the conduction anesthesia on the hand and foot by applying the methods already described by Krogius. Manz, after ligating the upper arm, injected a 0.5 to 1 per cent cocaine solution into the radial, ulnar, and median nerves of the forearm, and after ligating the leg, he injected the peroneal and tibial nerve just above the ankle. After twenty to forty-five minutes the hand and foot became absolutely insensitive, so that operations of any kind could be carried out on the hand and foot without pain. Similar experiments upon the hand and forearm have been reported by Berndt, Hoelscher, and Luxenburger. Berndt also described an amputation, according to the method of Gritti, which was performed with-

out pain. Gottstein reports a Pirogoff amputation carried out by this method. Arendt and Hoelscher used this same method for operations upon the penis. Berndt and Hoelscher held it to be more advisable to use larger quantities of dilute cocaine and eucaine solutions (0.2 per cent Hoelscher, 0.05 per cent Berndt) than smaller quantities of a 1 per cent solution, as recommended by Pernice.

Manz claimed not to have had good results with solutions more dilute than 0.5 per cent. Berndt, believing that the edema of the tissues produced by the injection of an indifferent solution would produce anesthesia, injected physiological salt solutions for this purpose. Luxenburger advised the injection of 2 per cent nirvanin solutions for anesthesia of nerve trunks. Hoelscher believed that nerve conductivity between the proximal and central parts of an extremity could be best interrupted by infiltrating all the tissues transversely with dilute solutions of cocaine. Hohmier has recently again adopted this procedure. He combined transverse infiltration with infiltration of the line of incision. The effect of the anesthetizing solution is greatly increased by injecting it between two constricting rubber bands placed about the extremity. This procedure (incarceration of the cocaine solution), which was used by Corning in 1885, has been recommended recently by Sievers. Practically all observers are of the opinion that considerable time is necessary for the interruption of conductivity of the larger nerve trunks of an extremity except the fingers and toes, and that the ligation of the extremity cannot be dispensed with, even though its application causes very considerable discomfort and pain to the patient during its use. It is only in very thin extremities that the pressure of the bandage necessary to interrupt the circulation is so slight as not to cause pain.

Just how much of the anesthetic effect upon an extremity so treated is to be ascribed to the medicament injected, and how much to the compression of the nerve trunks from the bandage, Manz is unable to say; whereas Kofmann claims that the ligation is the most important part and the injection of the anesthetic solution is entirely unnecessary. The anemia of the tissues produced by ligation (see Chapter III) affects sensation so late that it can hardly be considered an active factor of the anesthesia; whereas the ligation itself, if made sufficiently tight, can produce an interruption of the conductivity of the nerve trunks. It can therefore be said that in many of the reported cases in which anesthesia is supposed to have been produced by the injection of very dilute solutions of cocaine, or even of normal salt solution and in which it was necessary to wait a considerable time before anesthesia occurred, that the anesthesia was due not to the injection of cocaine but rather to the prolonged ligation of the extremity.

In 1903 the writer reported some results of experiments for producing conduction anesthesia—in fact, introduced the term "conduction anesthesia" to physiology and other related sciences. These experiments demonstrated that by means of the injection of cocaine, in connection with the ligation of an extremity or the addition of suprarenin,

the ulnar, radial, median, tibial, and peroneal nerves could be readily interrupted at certain points and that suprarenin could replace ligation. Following the interruption of conductivity, sensory and motor paralysis occurred; in the mixed nerves of the extremity vasomotor paralysis followed, so that the innervated area became hyperemic just as after the cutting of the nerves. According to the experiments of Heidenhain, the sensory nerves are usually affected before the motor nerves and the effects are also more lasting, so the former can be considered much more sensitive to the anesthetic than the motor nerves. The long subcutaneous nerves of the skin can readily be interrupted if a transverse strip of subcutaneous connective tissue is infiltrated according to the method of Krogius. On account of the overlapping of the innervated areas of one nerve with another, it will be necessary to anesthetize several nerve trunks in order to produce a practical and useful peripheral conduction anesthesia. Owing to vasomotor paralysis it may also be necessary to ligate an extremity in case mixed nerves are interrupted near the base of the extremity. If suprarenin has been added to the solution, it will not be necessary, while waiting for anesthesia to occur, to apply the ligature until just before beginning the operation. Absorption can, however, be still more delayed by the application of the compression bandage.

The use of suprarenin renders conduction anesthesia just as certain in other parts of the body as in an extremity. We have already spoken of the interruption of the supraorbital and occipital nerves, the cervical nerves where they pass from beneath the posterior edge of the sternocleidomastoid muscles and also the superior laryngeal nerves in operations on the larynx. Halstedt has already described the interruption of the inferior alveolar and lingual nerves. Another advancement followed the introduction of novocaine, whereby indefinite quantities of a stronger-acting anesthetic could be introduced without danger. All methods of conduction anesthesia were improved by the introduction of this drug, such as infiltration of tissue layers containing conducting nerve tracts, the circuminjection of operative fields, the blocking of nerve trunks, and better methods of operating in the areas supplied by the trigeminus, in operations upon the neck, operations upon the thorax, and in hernia in which conduction anesthesia by means of perineural injections is most important. More recently Laewen has introduced the precutaneous anesthesia of the sciatic and femoral nerve, and Hirschel and Kulenkampff a similar method for anesthetizing the brachial plexus likewise paravertebral and parasacral injections have opened new fields for conduction anesthesia. More definite information can be gained from the special chapters devoted to this subject. In general, however, it can be said that large individual nerve trunks are easily and certainly blocked by injection if their position can be determined by bony landmarks. Much more experience is necessary if these nerves are situated in the midst of soft parts. In the latter case the radiating peripheral sensations of paresthesia following the touching of the nerve trunks with the needle is the most certain method of determining the proper location of the

needle. In order not to be dependent upon the statements of the patients, Perthes constructed a needle, covered with an insulating material, through which he passed a faradic current; as soon as the needle touched a mixed nerve, contractions in the muscles supplied were readily observed.

[The use of the electric needle is of great assistance in locating nerve trunks, such as the sciatic, anterior crural, etc. An elaborate electrical apparatus is unnecessary for this purpose. The simple, inexpensive little device shown in Fig. 8, called a Tesla dynamo, to be found in any toy shop, answers the purpose very nicely and has the additional advantage of always being ready and never out of order. The needle should be insulated to within 2 to 3 mm. of the point. The positive pole is attached to the needle and the negative pole placed on any indifferent point on the surface of the body, using the usual moist electrode. As the needle is introduced in the direction of the nerve sought, an assistant turns the crank of the dynamo very slowly, one "click" at a time. Each "click"

Fig. 8.—Tesla dynamo.

produces a very slight electrical discharge. When the point of the needle comes in contact with the nerve, the electrical discharge causes a contraction of the muscles supplied by that nerve. The solution may then be injected directly on and about the nerve. Should non-insulated needles be used, failure may result as the side of the needle may be near enough to the nerve for the electrical discharge to produce a contraction of the muscles while the point, which has gone by, may be so remote that the solution when injected may not come in contact with the nerve.—Ed.]

Endoneural Injections of Anesthetic Solutions.—This method was first described by the American surgeons Crile, Matas, and Cushing. It consisted in introducing a needle into the several nerves supplying the operative field and injecting a small quantity of an anesthetic solution under the fibrous sheath or between the bundle fibers, in this manner thoroughly saturating the nerve and causing it to swell. By the use of

proper solutions the conductivity of the nerve was instantly interrupted just as though it had been cut with a knife. For the carrying out of this procedure it is necessary in most cases to freely expose the nerve trunk under local anesthesia at some distance from the field of operation. Crile carried out extensive experiments upon animals in reference to the action of cocaine and eucaine when injected into nerve trunks and found that these drugs did not differ markedly from one another in their action. He performed amputation of the leg five times with this method (the first operation occurring in 1887); the sciatic nerve was exposed in the gluteal fold and the femoral nerve in the inguinal fold, and cocaine or eucaine solutions were injected into the nerve trunks. The patients, after consenting to operation, were not permitted to know what was taking place so that the psychical effect of the amputation could be prevented. The interruption of the nerve trunks lasted twenty-five to thirty minutes. Matas, to whom credit for the terms *endoneural* and *perineural* belongs, carried out this same procedure in operations upon the foot and leg; the popliteal and saphenous nerves were exposed and infiltrated with a cocaine solution, whereupon complete anesthesia was produced from the knee down. Matas was able to centrally anesthetize the forearm and hand by infiltrating the freely exposed ulnar, median, and radial nerves, injecting into each of them 0.25 to 0.5 cc of a 1 per cent cocaine solution. The upper arm was then ligated, after which the operation was carried out and the wound sewed and dressed. Sensation returned about ten to fifteen minutes after the removal of the constricting band. Anesthesia of the brachial plexus was also attempted by Crile. Under infiltration anesthesia with a 0.1 per cent cocaine solution he exposed the brachial plexus and the subclavian artery at the posterior end of the sternocleidomastoid muscle and injected 0.5 per cent cocaine solution into each nerve trunk, using just sufficient of this solution to cause a small swelling of the nerve. The artery was temporarily clamped and the arm disarticulated at the shoulder-joint. The operation was painless with the exception of the posterior and outer skin incision. In a similar manner Crile performed amputation in the middle of the upper arm. He also performed a disarticulation of the upper arm with removal of the scapula, some general anesthetic being necessary, as was to be expected. Crile directed attention to the fact that the ulnar nerve at the elbow could very readily be injected with an anesthetic solution without previously dissecting it free, the interruption of conductivity following almost immediately after the injection. The peroneal nerve can be frequently injected at the bend of the knee. The trunk of the trigeminus can likewise be injected at the base of the skull as well as the Gasserian ganglion.

The necessity for freely exposing nerve trunks, as practised by Crile and Matas, and more recently recommended by Drüner so complicates anesthetic methods that this will only be done when there are definite contraindications to the use of a general anesthetic. Crile mentions as a particular advantage of this method of anesthesia that, with an interruption of the conductivity of nerves from the field of operation, shock

does not occur. Cushing and other American surgeons recommend the injection of the large nerve trunks before cutting them, even when an operation is carried out under general anesthesia, as, for instance, in disarticulations of the shoulder. The injection of anesthetic solutions into freely exposed nerve trunks is a sure and harmless method of anesthesia and will occasionally be found of use. This method would be very much simplified if it were possible to inject the nerve trunks exposed through the same incision as used for the operation itself. This method was made use of by Cushing in the operative treatment of inguinal hernia. By means of Schleich's infiltration anesthesia he freely exposed the inguinal canal and injected the ilioinguinal and spermatic nerves which lie under the fascia with a 1 per cent cocaine solution. As the result of this injection the hernial sac and its coverings, the spermatic cord, the testes, and a portion of the skin of the inguinal region became insensitive.

LUMBAR AND SACRAL (EPIDURAL) ANESTHESIA.

Lumbar anesthesia was discovered by Bier and introduced in surgery in 1899. Later it was learned that Corning in 1885 had already made experiments to produce anesthesia of the legs by injecting cocaine between the spinous processes of the vertebræ, but not into the spinal canal. These experiments, however, did not yield practical results. An anesthetizing solution injected into the lumbar sac of the spinal dura by means of a lumbar puncture, as suggested by Quincke in 1891, mixes with the cerebrospinal fluid and interrupts the conductivity of the nerve trunks of the cauda equina as well as of the roots of the spinal nerves with which it comes in contact. Lumbar anesthesia is, therefore, a form of conduction anesthesa. The effect of the anesthetic upon the nerve substance is more intensive since the intradurally placed nerve trunks and nerve roots are without sheaths. Very soon after the injection, anesthesia of the perineum appears first, then of the feet, which rapidly extends to the pelvis, to the navel, and under some conditions even higher. Motor paralysis of the legs and abdominal wall follows. The anesthesia lasts from one-half to two hours and motility returns before sensibility. Complete agreement in the choice of the anesthetizing substance to be used in spinal anesthesia has not yet been reached, but the majority of surgeons give preference to tropacocaine and, on the recommendation of Bier, add suprarenin to the solution, the importance of which is quite different here from what it is in local anesthesia, since the suprarenin in combination with tropacocaine loses, for the most part, its property of contracting the bloodvessels. The usual dose of tropacocaine is 0.05, the maximum dose 0.06. The firm of Pohl & Schönbaum, Danzig, supply sterile ampoules containing 1.25 cc of a 5 per cent solution of tropacocaine (=0.06) with 0.0001 of suprarenin and a trace of hydrochloric acid as a preservative; also tablets containing 0.05 tropacocaine and 0.0001 suprarenin. The tablets are to be dissolved in a small quantity of normal salt solution and sterilized by boiling. [Solutions containing suprarenin should not be

boiled, as this rather unstable substance is readily decomposed at high temperatures.—Ed.]

The author prefers also for lumbar anesthesia a solution of novocaine-suprarenin prepared from tablets. A tablet containing 0.125 novocaine is dissolved in 12.5 cc of physiological salt solution and the solution boiled. Of this solution 6 cc (=0.06 novocaine) may be injected for operations on the perineum and 8 cc (=0.08 novocaine) for operations on the legs. These doses should not be exceeded.

The instruments used consist of a 10 cc syringe that may be boiled and suitable hollow needles from 6 to 10 cm in length. The point of the needle should have a short bevel. The syringe and needles should be rinsed in salt solution in order to free them from the soda solution in which

Fig. 9.—Performance of lumbar puncture in the sitting position. (After Schmieden.)

they were boiled. A needle provided with a mandrin is commonly used, but for lumbar anesthesia the author prefers the ordinary thin needle used for local anesthesia, as it injures the tissues less than the thicker needle.

In performing lumbar puncture, the patient should sit on the operating table with the legs hanging over the side (Fig. 9). The head should be bent forward and the spinal column sharply flexed in order to separate the arches of the lumbar vertebræ as much as possible. Lateral bending of the spinal column is to be avoided. If the patient is unable to sit up, he may lie on the side with the legs drawn up and the back sharply flexed (Fig. 10). The upper edge of a towel stretched across the back at the level of the iliac crest crosses the spine, as a rule, at the spinous process of the fourth lumbar vertebra. The puncture is made at the first or second interspinal

space above this line. A wheal marking the puncture point is made exactly in the midline between the spinous processes. The skin is disinfected with alcohol and a needle passed straight in through the skin and interspinal ligament until spinal fluid escapes. Should the point of the needle strike against the bone, it should be withdrawn slightly and its direction upward or downward changed without deviating from the midline. The solution should not be injected unless spinal fluid flows freely through the needle. Should blood or bloody fluid escape, the needle should be withdrawn and passed at another intervertebral space. In the meantime the syringe containing the solution should be prepared in order that the injection may be made as soon as the puncture is successful. The injection should be made very slowly. The patient is then placed in a horizontal position. Elevation of the pelvis, which causes a

FIG. 10.—Performance of lumbar puncture in side position. (After Schmieden.)

displacement of the spinal fluid with its contained anesthetic upward, thus bringing it in contact with nerve roots higher up, should be avoided. Unfortunately, it is not possible with the most painstaking technic to prevent the failures (averaging about 9 per cent), the secondary effects and the dangers of lumbar anesthesia, which are due partly to the extension of the anesthetizing substance up the spinal canal to the medulla oblongata (paralysis of respiration, collapse), partly to the irritation of the meninges with abnormal pressure relations of the spinal fluid (headache, meningismus, meningitis), and, finally, partly to prolonged, irreparable damage to the nerve substance (paralysis). Toxic symptoms from absorption are seldom seen. Experience shows that with improved technic and more clearly defined indications the secondary and after effects have greatly decreased in frequency, though not entirely prevented. Mortality statistics of

lumbar anesthesia show very wide differences in the figures given, for instance, Tomaschewski estimates the mortality after lumbar anesthesia as 1 in 17,887, Strauss 1 in 2524, and Hohmeister and König 1 in 200. The latest large collection of personal cases is by the gynecologist Mayer. In 3310 vaginal and abdominal operations done under lumbar anesthesia he had 5 (6?) deaths, or 1 in 550, and 8 cases of severe asphyxiation. This agrees rather closely with the statistics of Franz, who in 3355 personal cases had a mortality of 1 in 479. This is a procedure, therefore, which, when used in this field of surgery, cannot be compared with general narcosis. Lumbar anesthesia, quite contrary to the original intention of its discoverer, has been set up as a rival of inhalation anesthesia. It is, however, nothing of the kind. It is an important addition to our methods of producing anesthesia, but it is a procedure like intravenous narcosis to be used only in an exceptional case and only in a hospital. It is almost universally agreed, however, that old people are particularly suitable subjects for lumbar anesthesia. In such patients recourse may be had to it when the employment of inhalation anesthesia seems to be hazardous (weak or reduced persons, heart or lung disease, potator), or local anesthesia is not possible or too technical. It should not be understood, however, that youth itself is a contraindication to lumbar anesthesia. Diseases of the nervous system and septic diseases of all kinds are contraindications to its use. Neurasthenics and hysterical persons bear lumbar anesthesia badly. Since the dangers and after effects of lumbar anesthesia increase considerably with the dose of the anesthetic substance and its extension upward, its use should be restricted in general to operations in regions supplied by nerves from the lower segments of the spinal cord, such as the perineum, sacral region (urethra, prostate, rectum), and the legs, while abdominal operations and operations in the lower abdominal region require a much higher anesthesia. Elevating the pelvis and similar procedures for the purpose of causing the extension upward of the anesthesia should be omitted.

With these limitations the author has used lumbar anesthesia frequently during the past few years in operations on the extremities, regularly for amputations for arteriosclerotic gangrene, without sepsis, in operations that require the prone position (popliteal space), and usually in fractures and dislocations, particularly when the patient has come to the operating room without preparation. In such cases lumbar anesthesia without doubt has decided advantages over general narcosis and one is not justified in giving it up, for with the limitation mentioned its dangers and after-effects have greatly diminished.

The injection of local anesthetics through the hiatus sacralis into the epidural space as recommended by Cathelin (1901) has been developed by Laewen into a useful method (sacral or epidural anesthesia). Since the nerve trunks that pass through the epidural (intrasacral) space are covered with strong dural sheaths, and since the extension upward of the anesthesia depends upon the amount of the solution injected, a satisfactory effect is to be expected only when a considerable quantity of a strong (con-

centrated) solution is used. Anesthesia develops much slower (twenty minutes) than after lumbar anesthesia. With the patient in a sitting position, or lying on the side, Laewen injects into the epidural space 20 cc of a 2 per cent or 25 cc of a 1.5 per cent novocaine-soda bicarbonate solution. After the injection the patient is allowed to assume a half-sitting position and the anesthesia involving the region supplied by the sacral plexus will result (deep epidural anesthesia). The formulæ for the novocaine-bicarbonate solutions follow:

	2 per cent solution.	1.5 per cent solution.
Sod. bicarb. puris	0.15	0.2
Sod. chlorid.	0.1	0.2
Novocaine hydrochl.	0.6	0.75
Aquæ dest.	30.0	50.0

The substances may be mixed and preserved as powders, so that one powder dissolved in the stated amount of cold water will produce a solution of the strength desired. The prepared solution should then be boiled once and 5 drops of suprarenin solution, 1 to 1000, added. According to the author's experience the novocaine-bicarbonate is superfluous, as the usual novocaine-suprarenin solution with the addition of potassium sulphate (page 185) has the same effect.

Krönig and his pupils, Schlimpert and Schneider, have sought to extend the field of epidural anesthesia. By increasing the dose of novocaine and by elevating the pelvis, an anesthesia extending to the regions supplied by lumbar and dorsal nerves has been produced (high epidural anesthesia). Kehrer has simplified the technic of Krönig's clinic. He and Fischer have shown that the usual preparation of the patient as practised in Krönig's clinic of inducing scopolamine-twilight sleep in order to obtain anesthesia is not, as Laewen had supposed, necessary. According to Härtel's experience the use of novocaine-bicarbonate is also superfluous in the production of high epidural anesthesia.

The three cornered hiatus sacralis (Fig. 11) is closed with an elastic membrane. In order to find the hiatus the midline of the sacrum, which may be recognized by the sacral spines, is marked with a blue pencil. The extension of this line downward will cut the hiatus. With the patient lying on the side, it will be observed that the rima does not lie directly in the midline but deviates to the lower side. The cornua sacralia, which bound the hiatus, should now be located, which is quite easy in thin but often impossible in fat persons. When the point of puncture is determined, it should be marked with a wheal. A hollow needle with a mandrin is used to make the puncture. It is introduced perpendicularly (Fig. 12) through the obturating membrane, then directed in the long axis of the sacrum and passed into the epidural space, not to exceed 5 or 6 cm in order not to puncture the lumbar sac, which, as a rule, ends at the level of the second sacral segment. The mandrin is withdrawn and a short time allowed to elapse to see if blood, or more rarely spinal fluid, escapes from the needle. Should blood escape, most authors advise to abandon entirely the injection; but should spinal fluid escape, one need only with-

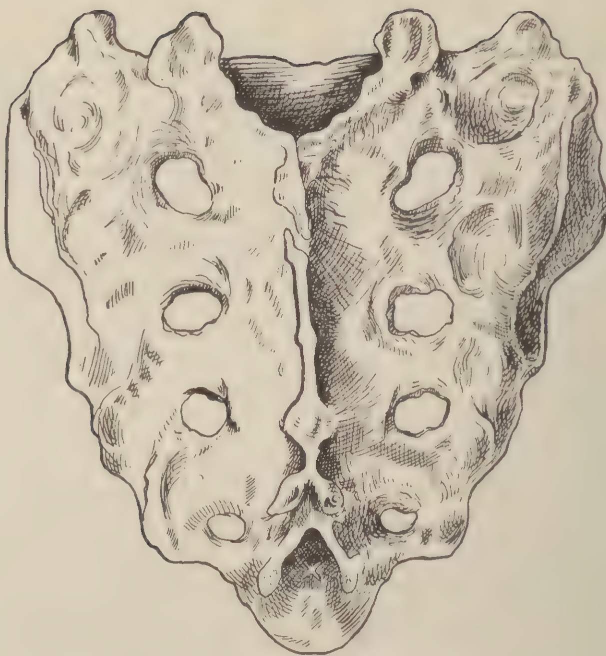


FIG. 11.—View of sacrum from behind.

FIG. 12.—Scheme for performing sacral puncture. (After Cathelin.)

draw the needle somewhat. The injection of the solution should be made very slowly. If the needle is in the right place almost no resistance is offered to the injection of the solution. Anatomical abnormalities at times make the introduction of the needle very difficult, or even impossible. In fat persons it is best not to attempt epidural anesthesia.

The puncture is made with the patient lying on the side (Fig. 13), or in the knee-chest position (Fig. 14), and since the pelvis is to be elevated immediately thereafter, the injection should be made with the patient on a properly arranged operating table. Fischer prefers to make the injection with the patient prone, and then places the body in a somewhat dependent position, as recommended by Schlimpert. This is easily accomplished by placing a triangular pillow under the patient's pelvis.

FIG. 13.—Performance of sacral puncture in side position. (After Laewen.)

The dose of novocaine as used by Kehrer for gynecological operations is 60 cc of a 1.5 solution, or in weak persons 50 cc. Fischer uses in operations on the upper half of the abdomen, on the legs, and in the region of the hips 70 cc of the same strength solution; in weak persons up to 50 cc, and in children under thirteen years of age, 30 to 40 cc. Kehrer proceeds with the injection in the following manner. The first 20 cc of the solution are injected rather rapidly, that is, in about twenty seconds, with the patient in the horizontal side position. The remaining 40 cc are injected slowly in the course of two to three minutes, with the pelvis of the patient moderately well elevated. After the injection is completed, the patient lies on the back with the pelvis elevated until anesthesia is complete. This requires about twenty minutes, and the anesthesia

extends up to the eighth dorsal segment. The anesthesia involves the legs, the pelvis, and the abdomen up to the umbilicus and the lumbar region. The anal sphincter and the abdominal muscles are relaxed. The anesthesia lasts from sixty to seventy minutes. Mild after-effects, pallor, dizziness, numbness, perspiration, and vomiting are frequently observed after epidural injections of novocaine, and in not a few cases severe symptoms, collapse, unconsciousness, and even death have occurred. Epidural anesthesia in the form of high sacral anesthesia, when used in operations on regions supplied by the higher cord segments, is as dangerous as lumbar anesthesia. It is free from its after-effects, but it is less certain

FIG. 14.—Performance of sacral puncture in knee-elbow position. (After Laewen.)

and technically more complicated. The after-effects may be attributable in some cases to puncturing a vein or the lumbar sac. As a rule, however, they are due to the normal absorption of the novocaine injected. Laewen and v. Gaza have shown experimentally that the rapidity of absorption from the epidural space is much greater than it is from the subcutaneous tissues and approximately almost that of an intravenous injection. Schweitzer has collected 3450 novocaine-sacral injections by different operators with 10 deaths, not all of which, however, can be regarded as due to the method. Kappis and Schmerz each report 3 deaths which are above criticism. Schweitzer advises, therefore, that the dose of novocaine does not exceed 0.4, or at most 0.5, and Laewen advises the greatest care

and caution in exceeding 0.4 novocaine in a 2 per cent solution in weak persons. High sacral anesthesia should be entirely rejected and the method limited essentially to blocking of the sacral plexus. Even here the method has a strong rival in local anesthesia in a restricted sense, namely, by parasacral anesthesia, that is, by filling the hollow of the sacrum with a weak novocaine solution, which likewise interrupts the sacral plexus and which is free from after-effects and failures, while failures are frequent in epidural anesthesia. According to Schweitzer, every fifth or sixth case is a failure. From present experiences we cannot predict a great future for epidural anesthesia.

VEIN ANESTHESIA.

In 1908, Bier devised a very effective method for bringing anesthetic solutions in contact with nerve substance. He injected a solution of novocaine into one of the subcutaneous veins, freely exposed between two constricting rubber bandages, the space between which had been previously rendered bloodless. Experimental investigation had shown that the vein walls were particularly permeable to watery solutions. The injected solution permeated the entire section of the limb very quickly, producing between the two bandages a terminal anesthesia. This Bier called "direct vein anesthesia." The solution permeates this area, also those nerves passing to other parts of the limb, blocking them and giving rise to indirect vein anesthesia in the entire portion of the limb distal to the ligatures. The technic of vein anesthesia has been described in detail by both Bier and Haertel, and is as follows: The entire extremity is sterilized, elevated, and made bloodless by a rubber band carried from the toes or fingers to above the place where the injection is to be made. Immediately above this bandage a second rubber band is passed about the extremity. The first bandage is then removed for a distance of not less than a handbreadth and not more than three handbreadths from the upper bandage. At this point the second compression bandage is placed (Fig. 15). For peripheral portions of a limb direct anesthesia can be carried out with one constricting band which, however, should not be placed higher than the middle of the forearm or leg. Operations on infected tissues should only be carried out by indirect vein anesthesia. For this purpose a compression band is placed above the infected area, and at this point the bandage for producing the anemia begins. The second compression bandage is then placed above the latter. Just under the upper constricting band one of the larger subcutaneous veins, such as the cephalic, basilic, median, or great saphenous, is freely exposed under infiltration anesthesia. In order to render the location of the veins certain it is advisable, before applying the bandage for producing the anemia, to mark the course and position of the vein or expose the vein before applying the bandage. The author advises the latter method, so that the patient will not be allowed to suffer from the compression bandage remaining unnecessarily long upon the limb.

The syringe recommended by Bier (Fig. 16) is of 100 cc capacity, connected with a cannula by means of a thick-walled rubber tube. The

Fig. 15.—Ligation for vein anesthesia.

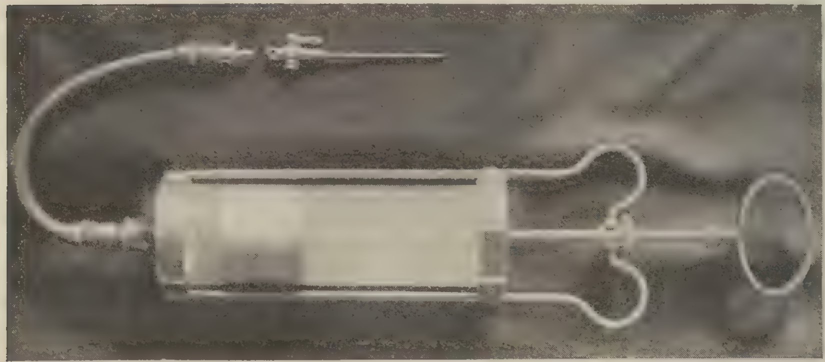


Fig. 16.—Syringe for vein anesthesia.

cannula is provided with a cock so that it may be closed, and has two furrows at its end for the purpose of tying it into the vein. The cannula

is tied into the vein in the same manner as for salt infusions, except that it is tied into the peripheral and not the central end of the vein. Injections are made under even pressure, or, as occasionally happens, very strong pressure, until the vein valves are overcome, 0.5 per cent novocaine solution without suprarenin; 40 to 50 cc for the upper extremity and 70 to 100 cc for the lower extremity, depending upon the thickness of the limb. If during the injection some of the smaller branches are seen to spirt they must be immediately closed with hemostatic forceps. After completing the injection the cannula is closed by means of the cock and the vein is ligated and cut, the small wound being closed by suture. Complete anesthesia will occur throughout the entire transverse section of the limb in about five minutes; indirect anesthesia as well as complete motor paralysis in the peripheral part of the limb follows in about five to fifteen minutes. At this time the peripheral constricting band can be removed in case it interferes with the performance of the operation.

The anesthesia lasts as long as the upper constricting band is kept in place. As soon as it is removed, sensation returns in a few minutes. According to the observation of Bier, the addition of suprarenin to the novocaine solution does not prolong vein anesthesia very materially, but it frequently prevents an even distribution of the injected solution throughout the transverse area, for which reason it should not be used.

Vein anesthesia may be used in suitable cases and is without danger. Poisoning from novocaine need not be feared following its use. The cases most suitable for vein anesthesia are resection of joints and amputations from about the middle of the thigh or upper arm downward. This method should not be used when operating for senile or diabetic gangrene (Bier). It is also a question whether this method should be used in septic infections, as it is possible to open a vein which is infected, even if some distance from the diseased area.

The upper constricting bandage causes severe pain after a short time. Perthes has devised a compressor which has relieved this somewhat. Momburg advises after anesthesia has set in that a second compression bandage be placed in the area of direct anesthesia and the bandage causing the pain removed. The rapid return of sensation following the removal of the bandage is very inconvenient in amputations. The operation must have been previously completed, thus rendering hemostasis very difficult. The literature on the subject of vein anesthesia is very scanty. Schlesinger believes it is possible to dispense with the artificial anemia by the injection of larger quantities of novocaine solution. He punctures a congested vein with a thin trocar, places the constricting bandage, and injects. This method does not explain, however, the manner in which the pressure of the vein valves is overcome. Jerusalem, Mantelli, Hitzrot, Goldberg, and Petrow report successful results with this method. von Eiselsberg states in the discussion of the report of Jerusalem that he only used the vein anesthesia when other anesthetic methods were contraindicated. The author holds this ingenious method of Bier to be a vaulable addition to our anesthetic methods in performing aseptic operations upon

the extremities when the usual local anesthetic methods are not possible. Bier himself limits this method of anesthesia to those cases in which local anesthesia is not possible. [It is difficult to conceive of a case suitable for vein anesthesia in which the parts could not be rendered anesthetic more easily and effectively by nerve blocking. The proper field of usefulness of vein anesthesia therefore is negligable.—Ed.]

ARTERIAL ANESTHESIA.

Alms and Maurel were the first to describe the anesthetic effects following the intra-arterial introduction of cocaine with consequent paralysis of the muscles in the area supplied by the artery injected (see page 80).

Goyanes, a Spanish surgeon, reported in 1909 the practical application of arterial anesthesia, and stated in 1910 that he had performed amputations and resections in 23 cases, with its use. In 20 of these cases complete anesthesia was obtained. Ransohoff amputated the forearm, using arterial anesthesia, and Oppel performed many operations upon the hand and foot, using the radial, dorsalis pedis, femoralis, and brachialis as arteries of injection. The leg is made anemic and ligated; below the constricting ligature the artery is exposed and the anesthetic injected by means of a fine needle. Goyanes used for this purpose 50 to 100 cc of a 0.5 per cent novocaine-suprarenin solution. Smaller doses were found insufficient by Oppel. Goyanes recommended this method particularly for the upper extremity, preferring lumbar anesthesia for the lower extremity.

Hotz has recently controlled the experiments made for arterial anesthesia. He recommends that the artery be exposed under local anesthesia and the leg made anemic just as in vein anesthesia and ligated above. A fine needle is then passed obliquely into the artery and a 0.5 to 1 per cent novocaine solution with suprarenin injected. For the brachial artery 20 to 25 cc are necessary. For the femoral artery 40 cc of a 0.5 per cent novocaine-suprarenin solution should be used. One or two minutes after the injection complete anesthesia occurs in the area supplied by the artery. Following the use of stronger novocaine solutions (3 per cent) severe pain occurs. After relieving the constricting bandage sensation returns immediately. In this manner 10 operations were performed on the hand, forearm, foot, and leg. In 3 lean patients it was found possible to inject the novocaine solution into the femoral and brachial arteries without exposing them. In these cases the injection was rapidly made and the leg immediately ligated.

Injurious effects were not observed. This method, according to Hotz, does not enter into serious competition with inhalation or local anesthesia. It is of value in tuberculous patients, in the aged with bronchitis and heart lesions, and other cases which are not suitable for general anesthesia.

That the extremity must be ligated above the anesthetized area and that sensation returns very quickly after releasing the constricting bandage is a disadvantage that exists with arterial anesthesia, just as with

vein anesthesia. Arterial anesthesia possesses the added disadvantage over vein anesthesia in that it is much more difficult to find the artery than a superficial skin vein. This method should scarcely be given further consideration in anesthesia of the upper extremity, as plexus anesthesia is a much easier procedure.

The above-named authorities, as well as Girgolaw, claim that the intra-arterial introduction of an anesthetic is less toxic than that introduced intravenously, but this is of no practical importance, as the ligating of an extremity according to the method of Bier renders such danger impossible. Experiments which the writer made on animals in 1900 also contradict any such theory (see page 86). The toxicity of these methods depends upon the manner of injection. If cocaine is injected into a previously ligated or clamped artery its toxic action is naturally much less than if this poison were injected into a vein with an uninterrupted circulation. If, however, the cocaine is injected into the circulation of a vein previously ligated or clamped, as is done in Bier's vein anesthesia, the toxic action will naturally be much less than if injected directly into an unobstructed artery. Therefore, we can say with equal right that cocaine injected intravenously is less toxic than when injected intra-arterially. [The remarks made under vein anesthesia are equally if not more applicable to arterial anesthesia.—Ed.]

CHAPTER X.

THE VALUE, INDICATIONS, AND GENERAL TECHNIC OF LOCAL ANESTHESIA.

Local anesthesia is not of like value in all branches of surgery. In ophthalmology, laryngology, and rhinology it has been the most important means of anesthesia for some time past. In urology and gynecology it is of much importance. In otology it is of less but still of considerable importance. With the introduction of suprarenin the importance of this method of anesthesia in dentistry has been record-breaking. Many dentists have stated that the introduction of this agent has been of the same importance to them as general anesthesia to the surgeon. The best evidence of the importance of local anesthesia in dentistry is the space given to this subject in the literature of the last few years. The value of local anesthesia in surgery was quite uncertain until the discovery of cocaine. Then it rapidly reached its climax.

In the years following its discovery many different ways of using cocaine were tried in surgery with varying results, such as infiltration anesthesia, conduction anesthesia, lumbar anesthesia. The beginning of the downfall of this method began with cocaine poisoning, but interest was again renewed with improvements in technic by Reclus and Schleich. It seemed as though infiltration anesthesia was to be the most important method of anesthesia, as conduction anesthesia, even by the circuminjection method of Hackenbruch, gave practical results only on ligating an extremity. Infiltration anesthesia left much to be desired, and it would have been soon forgotten again had it not been for the introduction of suprarenin and the supplanting of cocaine by less toxic agents. These changes, together with the improvement in technic in other directions, helped to place the method again on a sound footing. The new technic is characterized by injections around the operative field, the blocking of individual nerves, and, where possible, combining these methods with infiltration of the line of incision, as described by Reclus and Schleich. Ligation is not necessary at present with conduction anesthesia, for which reason this method can be used equally well in other parts of the body. Conduction and infiltration anesthesia are by far the most important means of producing local anesthesia. The most important feature is the possibility of injecting into the body as much of a solution as desired, producing a local anesthesia of such intensity and duration as has never before been known. This fact alone placed anesthesia in the foreground in surgery and assured its further progress. Improvements in technic with the older agents would not have brought about this change. The intro-

duction of novocaine and suprarenin were just as important for local anesthesia as the discovery of cocaine.

Up to the present time the field of local anesthesia was limited to minor or so-called ambulatory surgery. Very few surgeons performed any of the classical operations of major surgery with the aid of local anesthesia; but of later years, thanks to the improved and simplified technic, this method has gained many adherents, as signified by communications from Roith, Nast-Kolb, Bier, Madelung, Axhausen, Hesse, and others. Statistics of various institutions demonstrate the extent to which it is used, not only in ambulatory cases but also in major surgery, as is graphically shown in the constantly rising curve (see Table).

Year.	No. of operations.	General anesthesia.	Local anesthesia.	Lumbar anesthesia.
		Heidelberg Clinic (Narath, Wilms).		
1906	1917	1633 (85.0%)	218 (11.4%)	33 (1.7%)
1907	1936	1377 (71.0%)	426 (22.0%)	106 (5.5%)
1908	2070	1460 (70.5%)	559 (27.0%)	20 (1.0%)
1910	2303	1583 (68.7%)	632 (27.4%)	2
1911	2532	1063 (42.0%)	1375 (54.2%)	10
		Hospital of Stettin (Hesse).		
1908	1762	1364 (77.3%)	199 (11.3%)	15 (0.8%)
1909	1940	1294 (66.7%)	413 (21.3%)	26 (1.3%)
		Hospital at Zwickau (Braun).		
1908	1529	1078 (70.3%)	375 (24.8%)	4 (0.2%)
1909	1542	995 (64.5%)	489 (31.7%)	5 (0.3%)
1910	1811	1029 (56.8%)	727 (40.1%)	3 (0.1%)
1911	1898	987 (52.0%)	817 (43.0%)	9
1912	1866	903 (48.0%)	922 (49.0%)	5
1913	2248	1049 (49.2%)	1076 (50.5%)	3
		Surgical Clinic of the Charity Hospital (Axhausen).		
1910	1600	....	240 (15.0%)	
1911	1560	1124	461 (29.0%)	

During the past few years the proportion of 50 per cent local anesthesias has been slightly exceeded, although I have been obliged to test thoroughly all new suggestions. Holzwarth reports that in Dollinger's clinic local anesthesia is used in 94 per cent of all operations. There are many reasons against so extensive an elimination of narcosis. The latter cannot be dispensed with. Physicians not only in the university clinics, but in all hospitals, must learn to give a good anesthetic. That cannot be done if more than 90 per cent of all operations are performed under local anesthesia. The older methods of local anesthesia were practically without danger, and therefore in that respect came into competition with narcosis. In the endeavor to increase the field of usefulness of local anesthesia by the employment of larger doses of novocaine and by extending its use to new points of attack, a limit has been reached which in itself has dangers and disadvantages. On the other hand, the technic of narcosis has been materially improved. The restriction of chloroform narcosis,

the improvement in the technic of ether narcosis, the introduction of mixed narcosis, the general principle of narcotizing less deeply than formerly, the adjustment of the degree of narcosis to the particular phase of the operation, and, finally, the introduction of the ether mask of Sudeck and the chlorether mask of Kulenkampff have materially lessened the danger which threatened the patient during and after narcosis.

Persons with a highly psychic disposition are not suitable subjects for local anesthesia. This is necessarily a very elastic expression which admits of very different interpretations. In any event, it is a mistake to torture a patient with fearful apprehensions, but in the majority of such patients fear may be overcome by the preliminary use of scopolamine and morphine. The author favors this method for operations that can be done under local anesthesia in spite of the occasional irregular action of scopolamine. Two hours before the operation, the patient is given 0.01 morphine, with 0.003 to 0.005 scopolamine, at the same time the eyes are bandaged, and the ears plugged with greased cotton. If at the end of an hour the patient is not asleep, or if the sleep is not deep enough, the same or half the same size dose is repeated. As a rule, the patient, after the operation, does not know what has been going on. Kredel rightly states that children are by no means entirely unsuitable subjects for local anesthesia, since many of them are easily influenced and with the aid of chocolates or other sweets one may often induce them to submit to the injections.

A clever way of preparing nursing infants for local anesthesia has been suggested by Kredel. The baby is first allowed to become hungry. Then at the beginning of the injection it is given a bottle, after which it does not concern itself with what goes on.

Certain secondary effects may be mentioned which, so far as the indications for local anesthesia are concerned, are of little importance. It is stated that the after-pains following local anesthesia are more severe than after narcosis. This may happen occasionally. The author has seen a very uncomfortable intercostal neuralgia last for two weeks following a gall-bladder operation done under paravertebral anesthesia. According to the author's experience after-pains, as a rule, do not occur. There is nothing to add to what Honigmann has already said on this subject. After-pains following operations depend upon many conditions among which the method of anesthesia plays but a minor role. Moreover, they may be relieved easily; hence it is not worth the trouble to discuss them. Local injury to the tissues may possibly result from the substance injected even when the solution has been properly prepared. Injections, therefore, should not be made into tissues whose nutrition is already damaged. Since vessels, nerves, and other organs may be injured by the needle, it should be as small in diameter as practical. Such secondary effects are of importance in certain forms of local anesthesia which will be mentioned later.

A statement of Morians that novocaine has a harmful effect on the kidneys has not been confirmed by the investigations of Flory. In those

cases in which albumin has been found in the urine after operation, the albuminuria is to be referred to other causes than the novocaine. At all events, novocaine is much less harmful to the kidneys than narcosis. This opinion cannot be shaken by the recent communication of Orth, who found albuminuria after four hernia operations. Two of these patients, however, had recently had a nephritis. Of more importance in so far as the indications are concerned is the poisoning due to the absorption of the novocaine, since it is that which chiefly determines the limitations of local anesthesia. With older forms of local anesthesia, poisoning occurred too infrequently to permit percentages to be given or to influence the indications for their use. Symptoms of poisoning appeared more frequently when the effort was made to greatly extend the field of application of local anesthesia. Such symptoms were observed almost exclusively after injections in the immediate neighborhood of the vertebral column (concerning novocaine poisoning, see page 120).

In general, local anesthesia possesses material advantages over narcosis. Its employment within certain limitations is almost entirely free from danger. The general condition of the patient is not disturbed; the after-effects which at times follow narcosis and which influence unfavorably the course of the disease are absent, particularly vomiting. Ambulatory patients require no further observation, but may be dismissed after the operation has been finished. With local anesthesia an anesthetist is unnecessary; however, it is desirable at times during a very long operation to have someone to busy himself with the patient ("moral anesthetist" of the Americans). An advantage not to be underestimated is the "bloodless" field of operation, due to the use of suprarenin, which in certain operations is of decided importance.

As to the limitations of local anesthesia, one need not be concerned about the field of minor surgery, only in short interferences, particularly in infected regions, for example, in the opening of furuncles and phlegmons preference should be given to narcosis, particularly light narcosis (Rauschnarkose). Otherwise the field of application of local anesthesia is almost unlimited. It takes precedence, presupposing a suitable psychic state of the patient. Its limitations, with few exceptions, are to be sought in the field of major surgery where operations are yet to be conquered by local anesthesia. In the following sections these limitations especially will be pointed out. They are not sharply defined, since between the points where the indications for local anesthesia on the one hand and narcosis on the other hand are clear and undisputed, there is a considerable range in which the character, experience, and practice of the operator must determine the method of anesthesia to be used.

The modern operating-table is very comfortable for the operator, but for the patient operated upon under local anesthesia there is much to be desired. When, therefore, a particular position, such as a Trendelenburg or reverse Trendelenburg, is not necessary the patient should rest on a mattress placed upon a smooth table and covered with sterile rubber cloth and sheets, and thus made comfortable for the ordeal.

INSTRUMENTARIUM.

The instruments necessary for local anesthesia, especially for infiltration and conduction anesthesia, consist of syringes, needles, and receptacles for the anesthetic to be employed. Syringes of 2.5, 5 and 10 cc are necessary and must stand boiling. They should not be short and thick, but rather long and thin, so that the diameter of the piston is small and compact. The pressure of fluid in the needle is considerably greater the smaller the diameter of the piston. This is of much importance in injecting into dense tissues. The syringe should be well adapted to the hand and should have an attachment for making counter-pressure, such as a cross-bar or rings; or, what the writer believes best, a groove that will fit the second and third fingers. The "Record" syringe, made in Germany, consists of a glass cylinder with metal piston. It does not fulfil all the requirements mentioned, as it is too short and thick and has no arrangement for making counter-pressure. Hammer, in his criticism of this syringe, claims it requires too much attention. The piston must be removed when boiled, and, in spite of the best of care, the glass cylinders will occasionally break either during the boiling or cooling. On account of the great cost consequent on breakage, Hammer and the writer have given up the glass syringe for the all-metal one. Metal syringes are much better than in former years, and the operator soon grows accustomed to not being able to see the fluid.

FIG. 17.—Braun's syringe.

Fig. 17 shows the form of the author's syringe. Syringes with both barrel and piston made of metal without some means of packing have not stood the test, as the tightness of the piston soon wears so that the syringe is no longer usable. While the piston of the author's syringe is made of metal, it is provided with a changeable fiber ring which produces a durable and certain tightness, when it is swollen by taking up water, and it has to be changed only after long use unless it be injured in taking the syringe apart or in putting it together. It is therefore recommended not to take the syringe apart even when boiling it, and to have a care that the fiber ring be not permitted to dry out. By daily use of the syringe the latter takes care of itself. Where the syringe is not used daily it is best to preserve it in 1 per cent soda solution, which prevents the oxidation of the metal and the contraction of the fiber ring. With these precautions, the syringe is always ready for use, and it is almost indestructible. These syringes stood the test very well in the war where they were used because no repairs were needed.

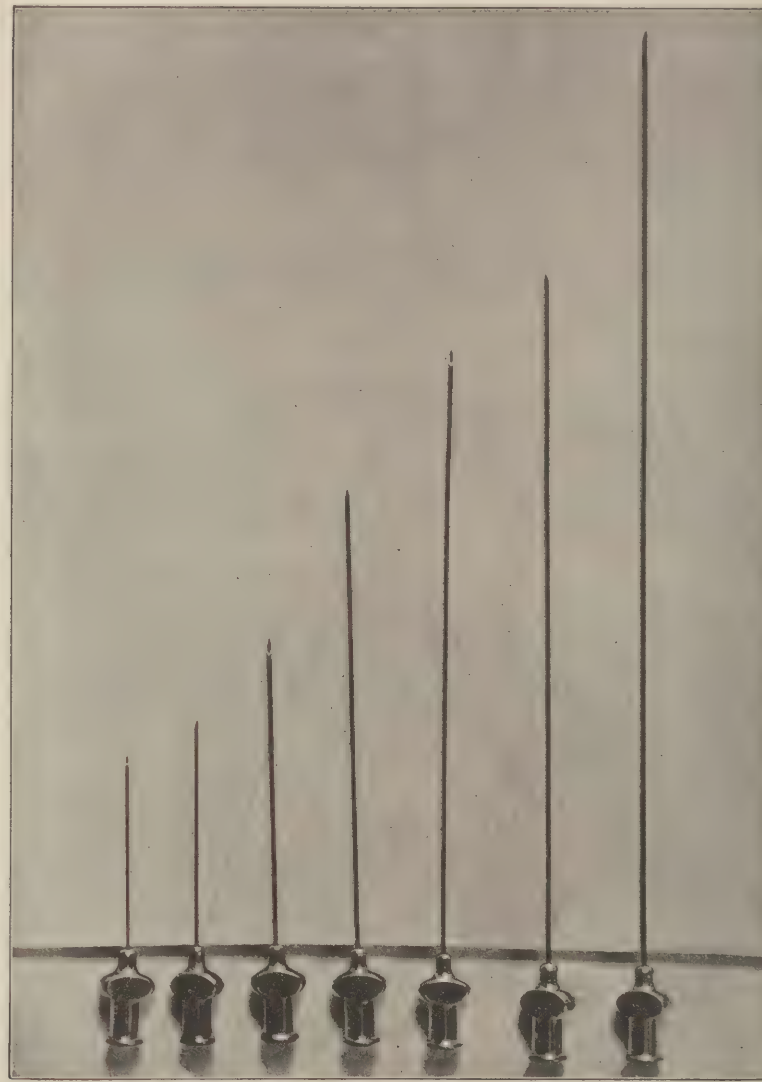
It is often necessary to introduce the needle detached from the syringe or to leave it sticking in the tissues while the syringe is being refilled. [It is always safer to introduce the needle detached from the syringe.—Ed.] All special devices for fastening the needle to the tip of the syringe should be avoided, since all of them hinder one more than the occasional blowing off of the needle, which is simply stuck on the end of the syringe without other means of fastening. When a long needle is fixed to the syringe in its long axis, it is often difficult to make a flat subcutaneous injection on account of the body form. Hackenbruch has had a syringe constructed so that the long axis of the syringe and that of the needle form an obtuse angle. It has the great disadvantage that in using it one cannot judge so well the location of the needle point. To be able to feel well with the point of the needle is the whole secret of local anesthesia. The difficulty just mentioned may be obviated by the use of the author's needleholder, in which the cone for receiving the tip of the syringe joins at an angle.

The injection apparatus (Spiegel, Stille, Moskowicz), which were described and illustrated in former editions of this work, as was foreseen, have not stood the test and they have not come into general use. Whether the injection apparatus recently brought out by Kuhn will share a better fate or not remains to be seen.

The needle should be as fine as possible without compromising its strength and rigidity in order not to cause secondary injuries, for example, by unintentionally sticking a bloodvessel. For that reason the author uses steel needles exclusively. Platinum and iridium needles are too expensive and nickel needles become dull too quickly. The point of the needle should have a sharp bevel and the needle must fit the syringe accurately. This may be easily tested by filling the syringe with fluid, then sticking the point of a needle in a cork and trying to press down the piston. No fluid should escape between the syringe and the needle.

Fig. 18 shows the full-size needles used by the author. Numbers 1, 3, 5, and 7 are the sizes most commonly used. Numbers 2 and 4 may be dispensed with. The short fine needle, Number 1, is used almost exclusively for making wheals at the point of injection. The injections always require the longer needles. Curved semicircular needles are unnecessary. The needleholder shown in Fig. 19 is a useful instrument for introducing the long needles (for example, in trigeminal injection, lumbar and sacral injection, etc.). The use of special needles with a graduated scale marked upon them is unnecessarily costly and at times inconvenient. A deviation from the usual form of needle has been devised by Schleich and consists of a cone-shaped end which is pressed into the end of the Schleich syringe (Fig. 20). This makes a very stable and tight connection, but cannot, however, be readily separated. The needles belonging to the syringe outfit of Schleich are too short. Complications, unpleasant for both patient and operator, sometimes result from breaking off and losing a needle in the tissues, and lawsuits often follow accidents of this kind. This mishap can occur with the most skilled, as it is

impossible at times to prevent the needle from breaking where it joins the hub. This of course applies to needles which have not been damaged



	1	2	3	4	5	6	7
Thickness .	0.5	0.5	0.6	0.7	0.7	0.7	0.9 mm.
Length .	25	30	35	60	80	90	125 mm.

FIG. 18.—Diagram showing needles in natural size.

by rust. For this reason it should be the rule that a needle must never be pushed into the tissues as far as the hub; it will then be impossible to

lose a broken needle in the tissues. Very long needles should be used in making injections into parts of the body difficult of access, as, for instance, injections carried out in the hidden recesses of the mouth, on the inner surface of the lower jaw, or the tuber maxillæ in dental operations. In

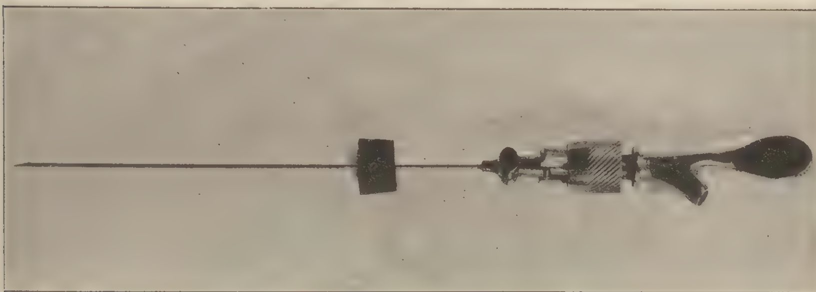


Fig. 19.—Needleholder, showing cork placed on the needle at a definite measured point.

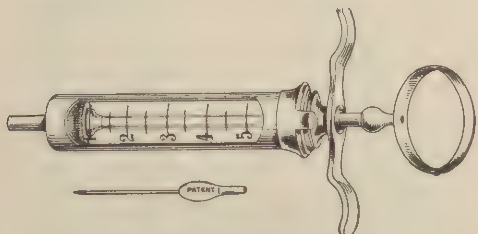


Fig. 20.—Schleich's syringe.

Fig. 21.—Porcelain dish for boiling tablet solutions.

operations at this depth, the needle should be of such length that it will not be necessary to have the syringe enter the mouth.

A small porcelain dish is necessary in which to boil the tablet solutions. Fig. 21 shows a very useful form.

For the preparation of the various solutions, glass graduates of from 5 to 20 cc capacity and porcelain measures of 150 to 250 cc capacity are necessary. The solutions can be used directly from these vessels. In the preparation of small quantities of the solutions watch-glasses, as used for microscopical purposes, are very satisfactory.

Syringes and needles are sterilized by boiling in a soda solution. This must be thoroughly removed by subsequent washing in salt solution, as

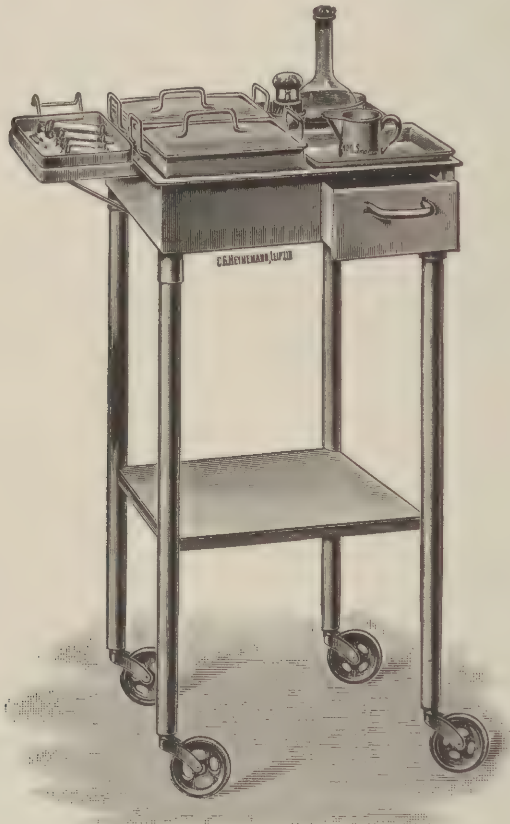


Fig. 22.—Table for local anesthetic apparatus.

both novocaine and suprarenin deteriorate in the presence of soda. After use, syringes and needles should be cleansed in alcohol and dried. Vessels and graduates should be sterilized by boiling, or may be kept in a 3 per cent carbolic acid solution until used again. They should then be thoroughly washed in salt solution. Fig. 22 shows a well-arranged portable table for the equipment necessary in local anesthesia. This table provides for instrument trays in which syringes and needles can be boiled, an enameled iron basin for salt solution used in washing the soda from

instruments, a similar basin for a carbolic solution in which graduates and other vessels are kept, a liter flask for salt solution, and a spirit lamp.

The apparatus as shown in Fig. 23 consists of a glass-top table having suspended from an upright a 250 cc glass graduate with a tapering glass end-piece connected to the graduate with rubber tubing closed by a pinch-cock. An alcohol lamp with a small porcelain vessel for dissolving and boiling the tablets and one or two other glass graduates complete the outfit. The advantage of this apparatus consists in dispensing with one assistant, of rapidly and accurately filling the syringe, and knowing the exact quantity of the anesthetic solution which has been injected.

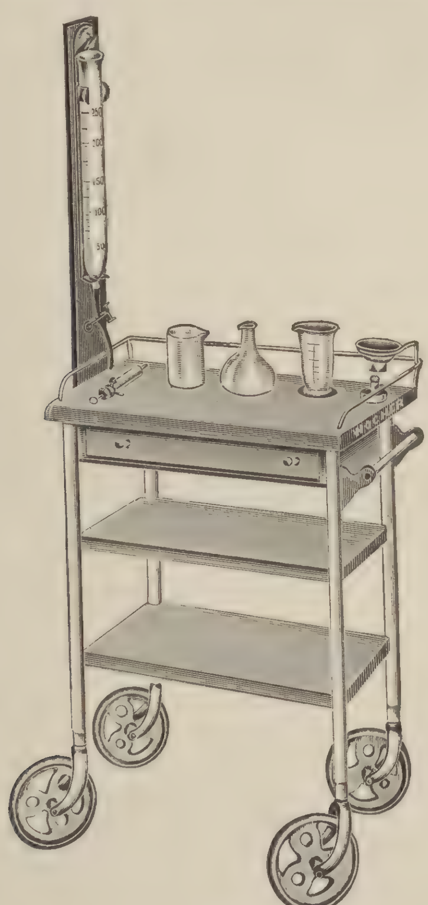


Fig. 23.—Shields' outfit for local anesthesia.

SOLUTIONS USED IN ANESTHESIA.

The solutions used for anesthesia should be isotonic as near as possible (see page 59), therefore physiological salt solution is used as the solvent.

To be exact, the strength of the salt solution should vary with the concentration of the anesthetic, but this is neither practical nor necessary. One must be satisfied with approximate values. A 5.4 per cent solution of novocaine constitutes a physiological solution, for which reason a 4 per cent novocaine solution is best prepared by dissolving in water instead of salt solution. Salt must therefore never be added to hypertonic solutions. All solutions, of course, must be sterilized. Cocaine, at least in surgery, has become obsolete. For infiltration and conduction anesthesia, novocaine combined with suprarenin is the combination of drugs most recommended. The author uses novocaine-chloride exclusively. He has not been able to convince himself of the greater effectiveness of novocaine-bicarbonate recommended by Laewen and Gros, but it can be easily shown that the addition of potassium sulphate as discovered by Kochmann and Hoffmann increases the effect of novocaine. It is recommended, therefore, to add 0.4 per cent potassium sulphate to the novocaine solution. The author cannot concur in the opinion of Hoffmann that a 0.1 per cent novocaine solution with the addition of potassium sulphate has the same anesthetic effect as an 0.5 per cent novocaine without such addition. We shall continue, therefore, to use the novocaine solution of the usual strength and shall add potassium sulphate merely for the purpose of improving our results. The addition of potassium sulphate presents no technical difficulty. One does not use as the solvent for novocaine physiological salt solution or water as heretofore, but a solution of 7.0 sodium chloride and 4.0 potassium sulphate in 1000 cc water. Novocaine can be sterilized by boiling, after which it will keep indefinitely. Suprarenin, on the contrary, is a very delicate drug, for which reason certain precautions are necessary in its use. The suprarenin of commerce is known by various trade names, viz., adrenalin, suprarenin, paranephrin, tonogen, etc. In Germany the American product adrenalin and the suprarenin of German manufacture are most commonly used. The latter is synthetically prepared and is placed on the market in a solution of 1 to 1000, with the addition of hydrochloric acid and an antiseptic, such as acetone, chloroform, thymol, etc., to ensure its stability. In this form the solution can be sterilized by boiling, and, if kept in alkaline-free glass, remains unchanged for a considerable time. Compressed tablets containing 1 mg. of suprarenin can be obtained, and tablets are likewise on the market containing the anesthetic drug with the requisite amount of suprarenin. In dental practice glass ampoules are preferred by many, each ampoule containing a small quantity of the anesthetic and suprarenal substance in solution. Preparations dispensed in this way have little to recommend them. They are costly and not fitted for physicians' use. The writer personally prefers the tablet as used in the dispensing of all alkaloids employed in medicine; this applies to unstable drugs particularly, such as suprarenin. Suprarenin is not stable in solution, while in tablet form it remains unchanged indefinitely. Diluted solutions of suprarenin become red quickly when exposed to the air without, however, losing much of their effectiveness. After longer exposure these solutions turn

brown and then are unfit for use. Lieble states, and with perfect right, that solutions made from the solid substance of suprarenin, particularly the tablets, are the most reliable. A chemist engaged in the manufacture of suprarenin writes: "The stability of suprarenin solutions is dependent upon many contingencies which cannot be avoided even with utmost care."

The sterility of the manufactured tablet cannot be depended upon even though the manufacturer claims the tablets are sterile. Hoffmann and Kutscher found bacteria in a number of tablets which they examined, and it is not a remote possiblity that pathogenic bacteria could also be found. Inasmuch as the dry substance cannot be sterilized, it is necessary to sterilize solutions made from these tablets before use. Solutions prepared from synthetic suprarenin can be sterilized by boiling without injury.

Anesthetic solutions can be prepared in various ways: 1. The writer has had prepared by Hoechster-Farbwerke[1] tablets of novocaine-suprarenin, so-called tablet A, containing 0.125 novocaine hydrochloride and 0.000125 of synthetic suprarenin in the form of a water-soluble salt, the tartrate being the one used at present. 1–2–4 of these tablets dissolved in 25 cc of physiological salt (potassium sulphate) solution produce 0.5 to 1 to 2 per cent solutions. The tablets necessary for an operation are placed in a small porcelain dish or sterile test-tube, covered with sufficient physiological salt (potassium sulphate) solution and sterilized by boiling. This solution is then placed in a porcelain vessel and diluted with salt (potassium sulphate) solution as desired, and used directly from this vessel.

2. Approximately 1 mg. of suprarenin is added to 200 cc of a 0.5 per cent solution, 100 cc of a 1 per cent solution, 50 cc of a 2 per cent solution and 25 cc of a 4 per cent solution. In institutions where large quantities of the anesthetic are required daily the following procedure will be of value. A 4 per cent novocaine solution to which is added 0.4 per cent potassium sulphate is sterilized and kept ready for use in cotton stoppered glass flasks. A tablet of 1 mg. suprarenin is dissolved as before mentioned and then boiled and added to 25 cc of the 4 per cent novocaine solution. This novocaine-suprarenin solution is now diluted with salt solution as desired.

3. At times it becomes necessary to prepare these solutions from a 1 to 1000 solution of suprarenin, for which purpose either the commercial preparation is used, which must be sterilized, or the solution is made from the suprarenin tablets and placed in a drop bottle. In preparing this solution 10 suprarenin tablets, each containing 1 mg., are added to 10 cc of distilled water to which 3 drops of dilute hydrochloric acid have been added; this is then boiled. Before using the drop bottle it is very necessary to know the number of drops per cc, as without this precaution the strength of suprarenin would be most unreliable, as the number of drops per cc varies between 10 and 20, depending upon the bottle. When the correct number of drops is known this amount of the liquid is added

[1] Hoechster-Farbwerke prepares novocaine and suprarenin in ampoule form, ensuring sterility.

to the requisite quantity of novocaine solution. It is best in preparing these solutions to have a graphic formula to work by as the following:

16 gtt. suprarenin solution 1 to 1000 = 1 cc = 1 mg. suprarenin.
to be added to

$$\left.\begin{array}{r} 200 \text{ cc } 0.5\% \\ 100 \text{ cc } 1.0\% \\ 50 \text{ cc } 2.0\% \\ 25 \text{ cc } 4.0\% \end{array}\right\} \text{Novocaine solution.}$$

From this diagram it becomes at once apparent how many drops of the suprarenin solution are necessary for larger or smaller quantities of the novocaine solution.

The use of tablets in the preparation of these solutions is the simplest and most trustworthy procedure, and, outside of hospitals, the only method to be recommended. It would certainly not be justifiable to have alkaloid solutions prepared by the druggist and then kept on the shelf until ready for use. In the German army hermetically sealed ampoules have been introduced containing a sufficient amount of novocaine-suprarenin and sodium chloride to make 100 cc of an 0.5 per cent solution, using sterile water. The addition of sodium chloride to the contents of the ampoule is not desirable, for if one wishes to make a concentrated solution with the contents of one of the ampoules it will contain too much salt, which may injure the nerves. The ampoules in general were satisfactory, although in the beginning of the war the suprarenin was without effect, probably on account of having been preserved too long, and notwithstanding the fact that the contents of the ampoules did not make clear watery solutions. The use of tablets, however, is the simplest and most reliable method of preparing solutions, even in war, for if one is not in a position to sterilize water or the solution, local anesthesia in general cannot be employed. The military boards, however, neither before nor during the war, considered it necessary to consult the author about these matters. The 0.5 per cent solution of novocaine-suprarenin is suitable for nearly all purposes. For injections just beneath the skin 0.4 per cent is sufficient, more concentrated solutions are reserved for anesthesia of the larger nerve trunks of the extremities or head, in cases where a rapid and peripheral anesthesia is desired. Since Laewen has shown that the 4 per cent novocaine-suprarenin solution is harmless, even in large quantities the author has been using this solution, and will describe it later in detail.

The dosage of novocaine and suprarenin has already been discussed on pages 119 and 141. More than 1.25 novocaine (250 cc of 0.5 per cent solution, 125 cc of 1 per cent solution) can be injected without toxic effect. In using the 2 to 4 per cent solutions it is best not to exceed 0.8 of novocaine, and if injections are made into dense vascular tissues like the gums, the fractional quantity of this dose should not be exceeded. This dose applies only to novocaine solution to which the proper amount of undecomposed suprarenin has been added. In using strong solutions, always observe Laewen's rule to *inject slowly*. It should be noted, furthermore, that in

injections in the immediate neighborhood of the spinal column, poisoning has been observed frequently after much smaller doses than those just mentioned.

As a rule, the dosage of novocaine need not be given much thought, provided no attempt is made to anesthetize too large an operative field. The progress of local anesthesia is based upon this fact. The reason why the dosage of suprarenin in local anesthesia is without consequence, and why the concentration of suprarenin in anesthetic solutions should not be exceeded, has already been discussed on page 141.

Solutions of alypin for anesthesia of mucous membranes can be prepared in the proper strength and necessary quantity from tablets containing alypin 0.2 and suprarenin 0.00033.

GENERAL TECHNIC OF INFILTRATION AND CONDUCTION ANESTHESIA.

Infiltration anesthesia and conduction anesthesia are theoretically entirely different procedures. In practice, however, they are not separated and must be considered together. Their development and relation to one another has already been described in Chapter IX, also the influence of modern anesthetic agents on their worth and technic.

We no longer attempt to systematically infiltrate the layers of the tissues in the proposed line of incision, as described by Reclus and Schleich. We anesthetize by infiltrating certain layers of the tissues alone, or in connection with the breaking of conduction of certain nerve trunks before their distribution in the operative field. It should be borne in mind that injections are not permissible in diseased tissues. In practice we seldom use the direct infiltration of the tissues, that is, infiltration anesthesia, but usually combine infiltration of the tissues with conduction anesthesia. It can be readily seen that a particular method of anesthesia is necessary for every operative field or part of the body. For the practical application of local anesthesia little is gained from the knowledge of the general technic of injection, but it is necessary to have a comprehensive knowledge of the sensory innervation of the operative field. For these reasons it is impossible to describe briefly the technic of infiltration and conduction anesthesia. In the surgical text-books of the future it will not be sufficient to place the subject of local anesthesia next to that of general anesthesia and dispose of it in a short résumé. The subject must be taken up fully and the technic for each operation given in detail.

Inasmuch as the injected agent does not immediately produce its maximum effect, either as to intensity or extent of anesthesia, except when the agent is injected endermatically, it is necessary to circumscribe the operative field by the requisite injections before beginning the operation. The injection of the deeper layers of the tissues should be made first, as the primary injection into the subcutaneous connective tissue would render the technic of the deeper injections more difficult. It is usually unnecessary to repeat injections during the operation, a distinct advantage

in that valuable time is lost in waiting for the anesthetic to become effective when repetition is necessary.

Anesthesia by means of injection, as carried out by Reclus and Schleich, was an integral part of the operation. Today it is independent of the operation, in fact precedes it, and need not be performed by the operator or in the operating-room. Before beginning the injections, the skin of the operative field should be sterilized with benzine or iodine-benzine, or the points of entrance of the needle can merely be touched with the tincture of iodine. After completing the injection, the preparation of the operative field is undertaken, such as the disinfection of the skin, surrounding the operative field with sterile towels, and the preparation of the operator and the assistants. During this preparation anesthesia has attained its maximum effect.

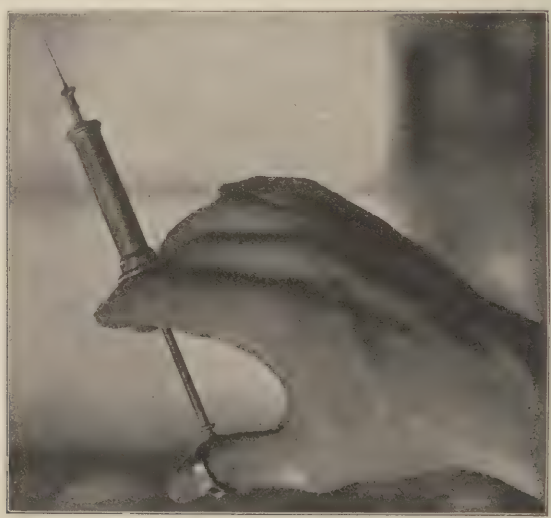


Fig. 24.—Manner of holding syringe.

The hand must be trained in the skilful manipulation of the syringe, which, as shown in Fig. 24, is held by the thumb, index, and middle fingers of the right hand. The wrist should be free, and all lateral pressure should be avoided to prevent the breaking of the needle, which must never disappear completely from view in the tissues, as already mentioned on page 180.

For the first punctures of the skin fine and short needles should be used (No. 1, Fig. 18). It is impractical and unnecessary to use ethyl chloride on the skin for the first needle punctures, as the skin is rendered hard and the insertion of the needle difficult; likewise the pain consequent upon freezing the skin is more severe than the pricking of a fine, sharp needle. It is often difficult to stick long, thin needles through the skin

on account of their great flexibility. Their introduction is facilitated by taking hold of the needle near the point with a forceps as shown in Fig. 25. The injections are carried out from several points, which are used for injecting with longer and thicker needles. It is therefore necessary to select points for injection and make them insensitive by the endermatic infiltration or the formation of a wheal, as described by Reclus and Schleich, the wheal formation at the same time renders the points visible to the eye. Points for injection should never be made upon sensitive parts like the flexor surface of the finger.

FIG. 25.—Introduction of a long, thin needle through the skin.

Endermatic infiltration is performed in the following way: The needle is inserted into the corium parallel to the skin surface with the bevel upward, avoiding the subcutaneous connective tissue until the opening of the needle has entirely disappeared in the tissues. A small amount of the 0.5 per cent novocaine-suprarenin solution is injected, thus producing a raised white area or wheal which instantly becomes anesthetic and at the same time marks the first point of injection (Fig. 26). The other points of injection are made in like manner. When the skin is very thin and movable, raise a fold of skin between the thumb and index finger and make the injection for the wheal as before mentioned. In certain portions of the body like the scalp, palm of the hand, the soles of the feet, the

endermatic injection requires considerable pressure, for which reason it is very essential to select a small syringe with a piston of small diameter for the formation of wheals. Schleich and Reclus began every operation with endermatic infiltration.

After the formation of the first wheal the needle may be inserted, if desired, into the anesthetic edge of each successive wheal; in this manner a small anesthetic line of any desired form and length can be outlined in the skin (Fig. 27). In case the skin is normal there is no objection to this method of anesthesia except that it is unnecessary, as the skin will become anesthetic without endermatic infiltration. For these reasons we only use the infiltration of the skin for the purpose of marking and anesthetizing the place of puncture of the needle.

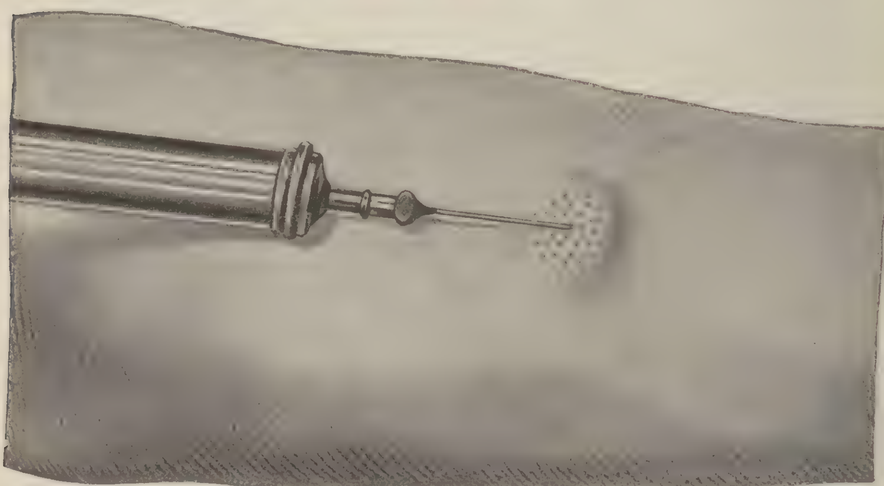


Fig. 26.—Formation of a skin wheal.

For the purpose of making a straight incision through the skin and subcutaneous tissue proceed as follows: One end of the incision where the needle puncture is to be made is marked by a wheal. A syringe containing a 0.5 per cent novocaine solution is attached to a long needle; this needle is then passed through the previously formed wheal into the subcutaneous connective tissue (Fig. 28), where under the guidance of the fingers of the left hand the needle is pushed parallel to the skin surface as far as the intended incision is to extend or as far as the length of the needle will permit (Fig. 25). If the fat layer is very thick, it is easy for the point of the needle to pass too deeply. This should be prevented by following the point of the needle with the index finger of the left hand, making gentle pressure on the skin. One should avoid unintentionally sticking the point of the needle into the skin from below, as this causes more pain than when the skin is pricked from without. During the insertion and withdrawal of the needle constant even pressure should be made

upon the piston, so that a narrow line of subcutaneous connective tissue is infiltrated. As to the necessary quantity of solution for injection, it is approximately correct to say that for every cm. of the proposed line of incision 1 cc of the solution be injected; with a 1 per cent solution a correspondingly smaller quantity is used. Immediately after the injection the skin of the area so treated is raised above the surface of the surrounding skin in the form of a low, narrow wall, which disappears in a very short time. The elevated line is then replaced by a white stripe in consequence of the rapid action of the suprarenin. In a few minutes this strip of skin becomes anesthetic, the injected solution having not only produced an infiltration anesthesia but at the same time the nerve supply to the skin has been interrupted, producing a conduction anesthesia of the overlying skin. This is the simplest form of conduction anesthesia. In case one point of puncture or the length of the needle is insufficient for infiltration of the proposed line of incision, injection from two wheals can be made corresponding to the ends of the incision (Fig. 28). At times it may be more desirable to make the wheal in the center of the proposed line of incision and inject in both directions. In irregular or angular lines of incision the injection can be carried out from the apex of the angle (Fig. 29, *B*) or from two points of injection (Fig. 29, *A*). The injection of the curved surfaces of the body by straight introduction of the needle from one point of injection naturally has its limitations, for instance, in the circular injection of the forearm. For this purpose four equidistant points for injection are selected

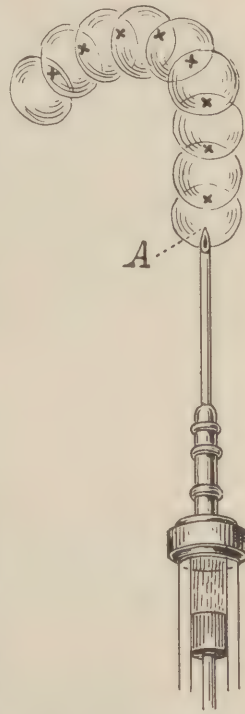


Fig. 27.—Formation of a series of wheals, according to Schleich.

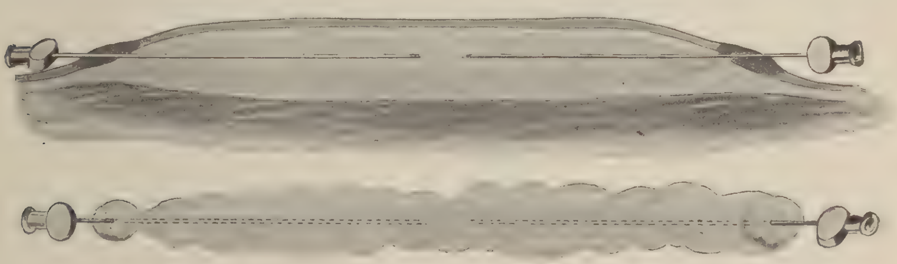


Fig. 28.—Injection of the subcutaneous connective tissue from two points.

from which the circular injection is carried out (Fig. 30). In the infiltrated area just described not only the subcutaneous tissue and overlying skin

become anesthetized, but likewise the entire area innervated by the cutaneous nerves passing through the infiltrated area.

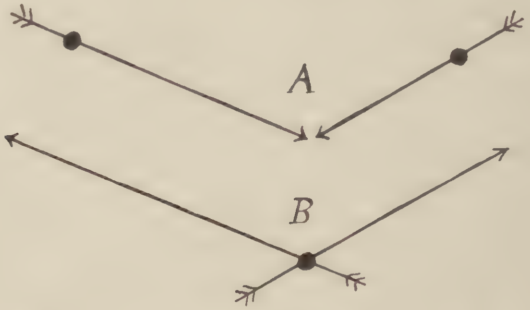


FIG. 29.—Subcutaneous injections made at an angle.

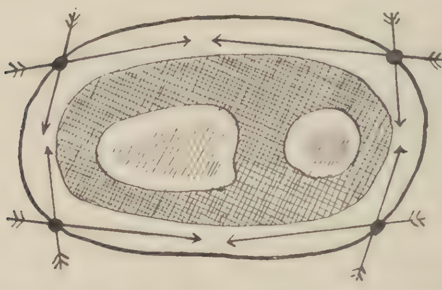


FIG. 30.—Schematic cross-section of the forearm. Infiltration of the subcutaneous connective tissue from four points.

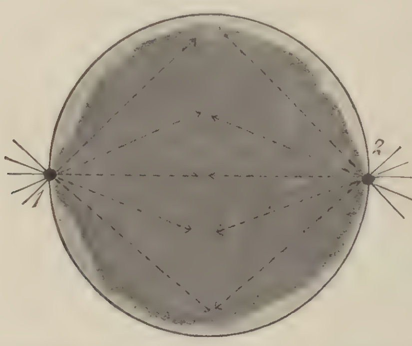


FIG. 31.—Superficial infiltration of the subcutaneous connective tissue.

If the subcutaneous connective tissue is systematically infiltrated in all directions from one, two, or more wheals, using a long needle, and injecting a 0.5 per cent novocaine-suprarenin solution during the insertion and withdrawal (Fig. 31), an anesthetic area of any desired size can be produced. In this manner extensive diseased areas of the skin can be

excised and in like manner this method can be used for the cutting of Thiersch grafts. Subcutaneous infiltration of the tumor base is sufficient for the excision of pendulous skin tumors (Fig. 32). The tumor itself should under no circumstances be infiltrated; it will then not become enlarged and resemble a cucumber, as has been stated by Schleich.

What has been said regarding the anesthesia of the skin and subcutaneous connective tissue applies to the mucous membranes, except in the formation of wheals. The injections, therefore, should be confined to the submucosa, which will necessarily render the overlying mucous membrane insensitive. In many parts of the body—for instance the scalp the sensory nerve trunks of the skin and fasciæ lie in the subcutaneous connective tissue for a considerable distance after leaving the fascia, for which reason large contiguous parts of the surface of the body have no direct nerve connection with the subfascial tissue. For this reason it is not always necessary to anesthetize the skin and sub-

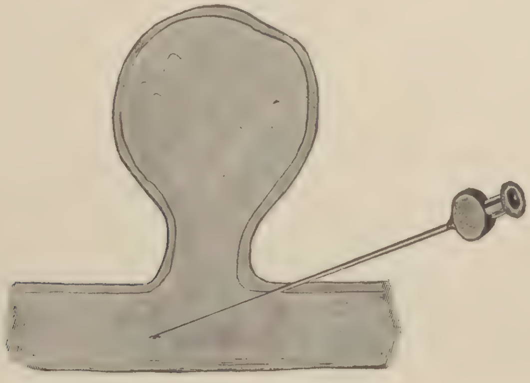


FIG. 32.—Infiltration beneath the pedicle of a skin tumor.

cutaneous connective tissue of the operative field, it being frequently sufficient to circumscribe the operative field by subcutaneous injections. Hackenbruch utilized these facts in his circular analgesia (Fig. 33). Wheals are made at points 1 and 2. From these points the subcutaneous connective tissue is infiltrated in the direction 1 to 3, 1 to 4, 2 to 3, 2 to 4, thus surrounding the entire field of operation by a subcutaneous wall of anesthesia in the form of an elongated rhombus termed Hackenbruch's rhombus. The longest diagonal of the rhombus lies in the direction of the proposed line of incision. Wheals can also be made at points 3 and 4 if more convenient, and the form of the encircling wall of the operative field may be square, circular, or any other desired form that the operation may require. The number and position of the points of injection are determined by the form and size of the operation (Fig. 34).

In certain parts of the body all of the sensory nerves supplying not only large areas of skin but likewise the deeper structures are located in

the subcutaneous tissues. As an example we might mention the sensory nerves, supplying the skin, periosteum, and bones of the skull, which in the neighborhood of the base, particularly the forehead, are found in the subcutaneous connective tissue. A simple circular subcutaneous injection,

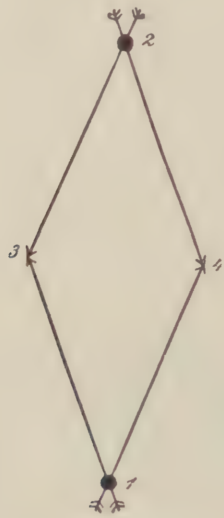


FIG. 33.—Hackenbruch's rhombus.

as shown in Fig. 34, can be used in outlining such operative fields on the cranium of any desired size and will produce complete anesthesia of all structures, including the bone. It may then be said that the Hacken-

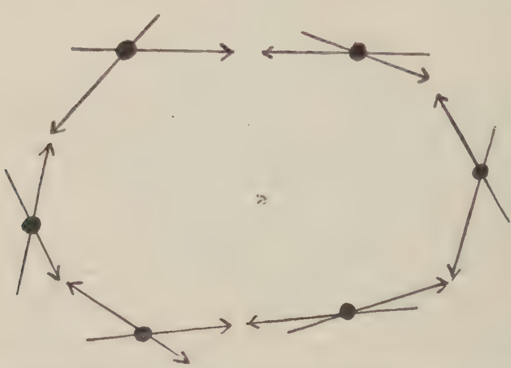


FIG. 34.—The subcutaneous circuminjection of an operative field from six points.

bruch circuminjection should be considered the normal procedure in anesthesia of the skull. Hackenbruch has rightly stated that anesthesia of a finger, as described by Oberst, depends upon this same principle, as the subcutaneous connective tissue of the finger base contains the sensory

nerves. If, therefore, the subcutaneous tissues of the finger base are circularly injected this entire member will become anesthetic.

It is only in such parts of the body having the type of innervation as already described that the subcutaneous injection alone produces a useful anesthesia. Anesthesia will not be complete in operative fields circumscribed by anesthetic injections if they receive their innervation from below. For example, if an operative field in the region of the chin is injected, having the exit of the mental nerve in its center, anesthesia will not occur. One of the most elementary procedures for the induction of local anesthesia consists in the systematic infiltration of the different layers of the tissues. The simplest form of this mode of anesthesia has been described by Schleich in connection with anesthesia for aspirating various cavities of the body (Fig. 35). The point of injection is marked

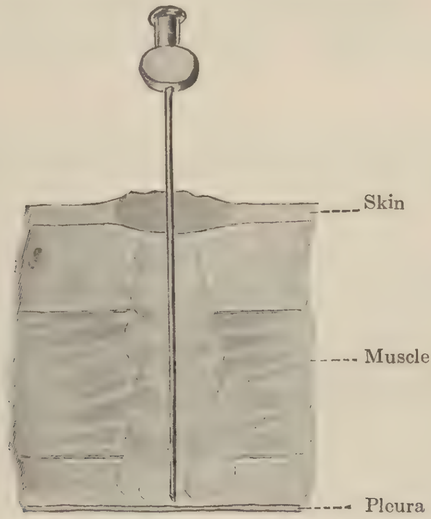


FIG. 35.—Infiltration of the needle tract used in aspirating the body cavities.

by a wheal; a needle of proper length is then inserted as far as the subpleural or subperitoneal connective tissue, injection of the anesthetic agent being continuous during the insertion and withdrawal of the needle. The infiltration should be ample, as mentioned in connection with the subcutaneous injections; however, it is unnecessary to go to the other extreme and render the tissues edematous, as in the Schleich method. The pleura and peritoneum never require infiltration, as the innervation of these structures is derived from the subpleural or subperitoneal connective tissue. This simple procedure may be amplified by infiltration of parts of the body to any desired extent (Fig. 36).

The arrows indicate the usual direction of the needle, which is inserted through two wheals. The injection is begun in the deepest layer, in this case the bone, and finished with the injection of the subcutaneous connective tissue. The needle is therefore inserted through one of the

indicated points into the subcutaneous connective tissue, then perpendicularly to the deepest point—the bone, subperitoneal connective tissue—and the injection carried out as for simple aspiration. The needle is then drawn back into the subcutaneous connective tissue and again passed to the same depth but in a more oblique direction toward the center of the area to be infiltrated. The last injection is made directly under the skin, as shown in (Fig. 26). During the insertion and withdrawal of the needle the anesthetic fluid must be constantly injected. If the needle is long enough, the anesthesia can be completed from one wheal placed either at the end or in the center of the line of injection.

It is never necessary in any part of the body to inject beneath the periosteum to render it insensitive, notwithstanding the fact that Reclus, Schleich, and others advised subperiosteal injections which, from a practical stand-point, were carried out with difficulty, if at all. The skin receives its innervation from the underlying subcutaneous connective tissue, for which reason, if the latter be infiltrated, the skin becomes

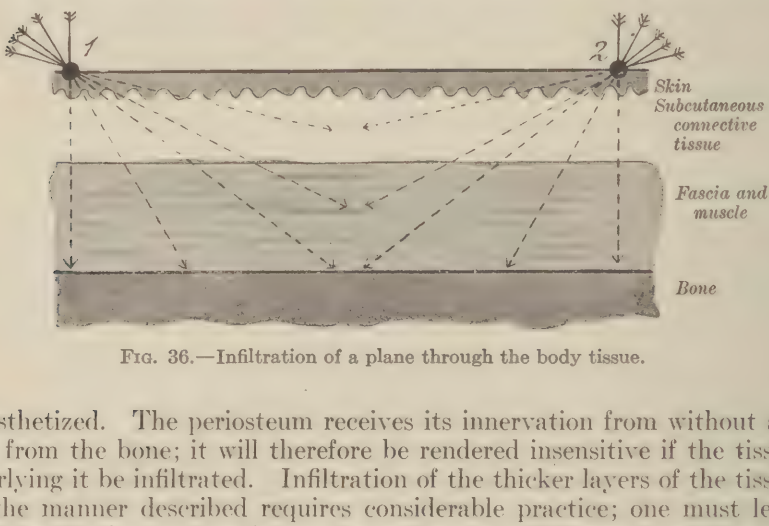


FIG. 36.—Infiltration of a plane through the body tissue.

anesthetized. The periosteum receives its innervation from without and not from the bone; it will therefore be rendered insensitive if the tissues overlying it be infiltrated. Infiltration of the thicker layers of the tissues in the manner described requires considerable practice; one must learn to feel with the needle-point, and must know at all times where the point of the needle is, for which reason an exact knowledge of anatomy is necessary. The hand holding the syringe must be able to detect the minutest change of structure, as when the needle-point encounters a layer offering certain resistance to its passage, and then passes into a connective tissue layer of softer and looser structure. The puncture of the muscle fascia always causes slight pain. To avoid injecting larger quantities of the anesthetic into a vein, the syringe must be in constant motion, injecting during the insertion and withdrawal of the needle, as has already been recommended by Reclus (*injection traçante et continué*). The continuous injection likewise causes an even distribution of the anesthetic in the tissues.

If injections are to be made in the neighborhood of large vessels care

should be observed. Sticking a bloodvessel is an indifferent event, but the intravenous injection of a large amount of the solution may prove serious.

This possibility comes into consideration when a large quantity of the anesthetizing substance is to be injected at a particular place through a "still" needle. In such cases one should always introduce the needle detached from the syringe and wait to see if blood escapes. Should this not occur, a few drops of the solution should be injected and the syringe again detached from the needle to see if bloody fluid return. When it is determined that neither blood nor bloody fluid escape, the injection may be undertaken, otherwise the location of the needle must be changed. It is very misleading to use suction with the syringe as particles of tissue may be drawn into the needle causing its obstruction.

The technic of the injection just described is sufficient for infiltration anesthesia of a narrow line of incision and conduction anesthesia in the area supplied by those nerve trunks which have been affected by the injection.

The first is practical when a simple incision is to be made through normal tissues, as, for instance, the removal of a foreign body when its position is definitely known. Conduction anesthesia produced by the above-mentioned infiltration is of much more importance in rendering the operative field insensitive.

Occasionally, by a simple infiltration of a narrow area, it is possible to interrupt the larger part of the nerve supply to the operative field. This is made use of in inguinal and femoral hernia operations. In other cases several areas must be infiltrated at the same time, which areas may be some distance from the field of operation, so that they will surround and isolate the operative field from the rest of the body.

The technic of these procedures can be more definitely shown by a diagram. Fig. 37 represents a pyramid with apex, 5, lying in the depth beneath the center of the operative field. Its base 1–2–3–4 is located upon the skin surface; its lateral surfaces bound the operative field. The first step is to endeavor to anesthetize these four lateral walls. The points 1–2–3–4 represent the points for injection. A long needle is inserted into each one of the before-mentioned points and injections made in the direction of point 5, then in various directions from the laterally located points, as 1 to 7, 4 to 7, 4 to 6, 3 to 6, 3 to 9, 2 to 9, etc. The subcutaneous connective tissue is finally infiltrated in the form of a Hackenbruch rhombus, in the directions 1–2–3–4. Shortly after the injection the field of operation becomes insensitive, whether it has come into contact with the anesthetic or not.

Two points of injection are often sufficient for the injection of this figure; in other cases four or more will be necessary, depending upon the extent of the field of operation. Sometimes it will take the form of a cone or a part of it, at other times a trough-like shape, as is shown in Fig. 38. Two points of entrance are designated in the diagram by 1 and 2. From these points injections are made in the directions 3, 4, 5, 6, 7, and, lastly, the subcutaneous tissue is infiltrated in the form of a Hackenbruch

rhombus. Fig. 39 shows how, in the case of bone, the operative field is surrounded by an encasing form of injection which renders all parts of the operative field insensitive.

For all these injections 0.5 per cent novocaine-suprarenin solution is the most suitable anesthetic; it interrupts the conductivity of small and medium-sized nerve trunks quickly and with certainty if the connective

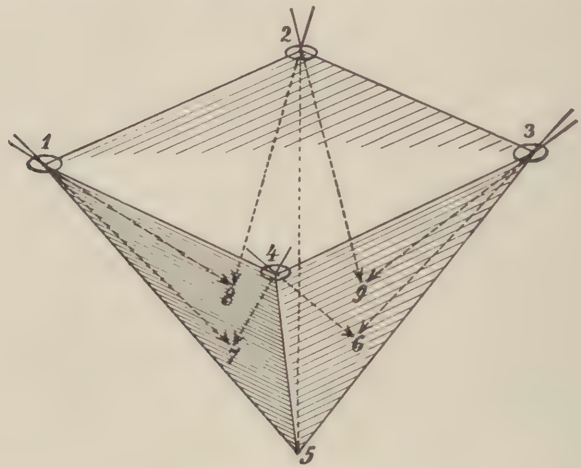


Fig. 37.—Pyramidal form of injection.

tissue layers containing the nerve trunks are infiltrated without necessarily hunting these nerves. Concentrated solutions of novocaine-suprarenin (1 to 4 per cent) are recommended in cases where large quantities of fluid might cause discomfort or injury, as in the orbit, eyelids, prepuce, the fingers, etc. It must be remembered that these concentrated solutions produce considerable effect on tissues situated at some distance from the

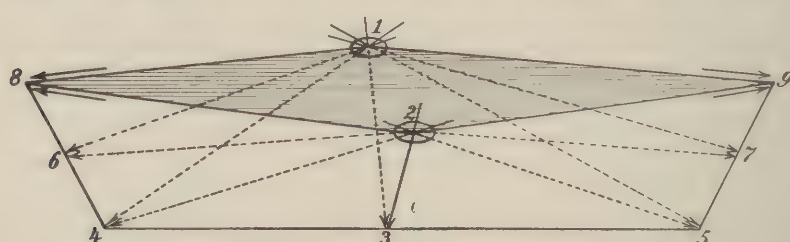


Fig. 38.—Encasing or trough-like injection.

place of injection. An injection of such a solution after a short time produces infiltration anesthesia not only in the area injected but likewise for some distance beyond, and nerve trunks will be blocked in passing through this area by the so-called indirect infiltration anesthesia. Much use is made of this method in practice.

The combination of direct anesthesia of the larger nerve trunks in

connection with the circuminjection of the operative field requires definite rules for its performance and is accomplished by a definite guidance of the needle. Seeking the nerve trunks with the point of the needle is easy and certain when the position of the nerve can be definitely located in connection with bony landmarks which aid in the guidance of the needle. It is much more difficult when these landmarks are absent and the nerve is situated in the midst of thick, soft parts. A good guide in all cases is the radiation of sensations of paresthesia toward the periphery, which occurs following the irritation of the nerve with the needle. If possible, the patient must be instructed in this regard before the introduction of the needle, and must be told to speak at once as soon as he notices the par-

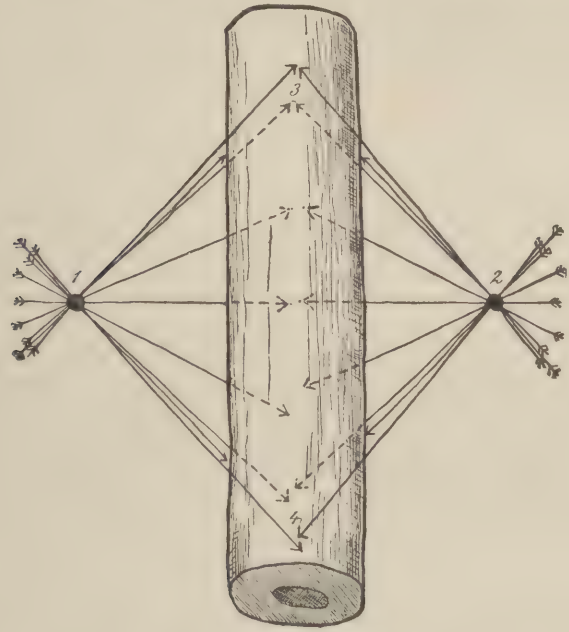


Fig. 39.—Encasing injection surrounding a bone.

esthesia. If these sensations occur, it is certain that the point of the needle is in the proper place. For locating mixed nerves the small electric apparatus of Perthes has proved useful at times. A small needle insulated down to the point is introduced in the direction of the nerve while a very weak galvanic or faradic current is passed through the needle. When the point of the needle comes in contact with the nerve, contractions are produced in the muscles supplied by the nerve. For the blocking of large nerve trunks it is advisable to use concentrated solutions as 1 to 5 cc of a 2 to 4 per cent novocaine-suprarenin solution. The length of time necessary after the injection for blocking to occur depends upon how the nerve was reached. If the needle can be introduced into the nerve trunk, as is possible after a little practice, for instance, with the branches of the

trigeminus, the interruption of conduction occurs instantly. If the anesthetic is injected only in the neighborhood of nerves, it will require five to twenty minutes before it interrupts the conductivity of the nerve.

Freely exposed nerve trunks can be instantly blocked if one injects into the trunk a 0.5 or 1 per cent novocaine-suprarenin solution. A spindle-shaped swelling of the nerve occurs which disappears very quickly. It seems as though the injected fluid is disseminated between the nerve bundles. It can therefore happen that, after an endoneural injection, branches of the nerve may be interrupted which leave the trunk proximal to the point of injection. In injecting nerve trunks it is especially important that the solution have the proper composition and that the sodium chloride content be neither too high nor too low, since the nerve fibers are very sensitive to edema and to the abstraction of water and may be permanently injured thereby. The method of injection in individual cases, whether it be infiltration, circuminjection, or blocking of the nerve trunks for the purpose of rendering the operative field insensitive, whether it deals with injury, removal of a foreign body, inflammatory conditions or tumors, is the same. The nature of the anesthesia will seldom be influenced by the nature of the disease.

Care must be taken to infiltrate a sufficiently large area around the operative field, allowing a certain amount of play, as it were, so as not to be cramped for room, for which reason the lines for circuminjection should never be too near the line of incision. That no injections should be made too near diseased tissues has been repeatedly mentioned, and injection into the diseased tissues themselves is, of course, not permissible. This latter applies particularly to septic infections. A small circumscribed furuncle can be injected in the form of a pyramid if the inflamed tissues are avoided; diffuse phlegmons are only suitable for anesthesia when nerve blocking can be accomplished some distance from the operative field. In incising furuncles and phlegmons light ether or ethyl chloride anesthesia is usually to be preferred to local anesthesia. [Nitrous oxide-oxygen anesthesia, if available, as a rule, is preferable to either for such short operations.—Ed.] Local anesthesia is not contraindicated for malignant growths if the entire operative field can be excluded without injecting into the immediate neighborhood of the tumor.

In excision of cystic tumors, retention cysts, bursæ, etc., it is sometimes advisable to deviate from the rule of completing the injections before operation, if the injection is made with difficulty. In these cases the approach to the cyst is made insensitive, and, after opening it, the surrounding parts are infiltrated from its inner surface before resecting the sac. Naturally, after making the second injection, time must be given for it to act.

It is needless to say that the operative fields most suitable for this method of anesthesia are those where innervation can be readily interrupted, as will be specified in the following chapters. The anesthesia of synovial membranes in aseptic joint operations already mentioned on page 145 and anesthesia for fractures and dislocations will be described according to the method of Quénu and Lerda in Chapter XVI.

CHAPTER XI.

OPERATIONS ON THE HEAD.

The head receives its sensory innervation chiefly through the trigeminus nerve. The occipital region, region of the ears, and the under border of the lower jaw also receive innervation from the spinal nerves occipitalis major and minor, auricularis magnus, and cutaneus colli. The trigeminus nerve innervates, besides the skin of the face, the bones and cavities of this part and the organs contained in them. The base of the tongue, pharynx, middle and inner ear are innervated by the glossopharyngeal nerve, while the vagus supplies the sensory innervation to the outer ear and drum.

OPERATIONS UPON THE SCALP, FOREHEAD, AND SKULL.

As will be noted in Fig. 40, the sensory nerves supplying the forehead, temporal region, and the scalp emerge and pass through the fascia and beneath the skin on a line approximately drawn from the occipital protuberance to the eyebrow, encircling the skull. They pass in a direction toward the crown of the head, where they subdivide. In this entire distribution the nerves are subcutaneous, that is, subfascial, for which reason an anesthetic area of any desired extent can readily be produced by interrupting these nerves. These same nerves innervate not only the skin and fascia but likewise the bone and periosteum of the crown of the head. The dura mater is only sensitive toward the base of the skull. The brain, as has been previously mentioned, is insensitive to all irritation (see page 33). For this reason the simple subcutaneous or subfascial circuminjection is sufficient to render anesthetic an operative field of any desired size for skull and brain operations. Only in those places where the skull is covered by muscle layers will it be found necessary to anesthetize these structures by an additional line of infiltration anesthesia. The circuminjection of a line running bilaterally from the eyebrows above the outer ear to the occipital region will render the entire top of the skull insensitive. The modern anesthetic agents permit us to inject an area of this extent without fear. Subperiosteal injections are never necessary and serve no purpose.

The circuminjection with novocaine-suprarenin solution serves not only for producing anesthesia, but inasmuch as the arteries supplying the skull run radially in the same direction as the nerves, they will undergo contraction, and as a result the operative field will be rendered bloodless. For this reason local anesthesia in skull operations makes the use

of various devices for stopping hemorrhage unnecessary, such as the temporary suturing of the scalp alone (Heidenhain), or in connection with metal plates (Kredel), or the clamping of the wound margins with spring clamps (Vorschuetz). Complete interruption of the circulation does not occur and should not occur from this method of injection. The larger arteries bleed slightly and must be ligated; hemorrhage from the smaller vessels, however, is absent. This method in skull operations is sufficient and possesses many advantages over the unsatisfactory provisional methods for stopping hemorrhage.

The author always uses 1 per cent novocaine-suprarenin solution for circuminjection on the skull. The 0.5 per cent solution contains too little suprarenin for such vascular tissues and may lead to complete failure.

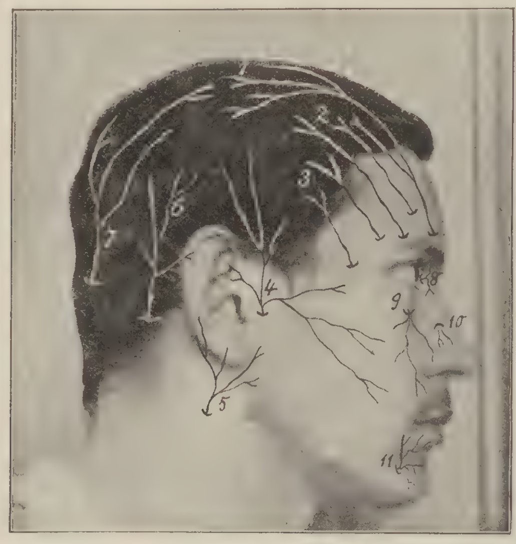


Fig. 40.—Points of emergence of the nerves of the head through the fascia and their course under the skin and aponeurosis of the occipitofrontalis muscle. 1, frontal; 2, supraorbital; 3, zygomaticotemporal (second branch of the trigeminus); 4, auriculotemporal (third branch of the trigeminus); 5, auricularis magnus; 6, occipitalis minor; 7, occipitalis major; 8, supra- and infratrochlearis; 9, infraorbital; 10, external nasal branches of the ethmoidal; 11, mental nerve.

[This, of course, applies only to solutions made with tablets containing a fixed amount of suprarenin and not to solutions of novocaine (procaine), to which suprarenin (adrenalin) may be added separately as desired. —Ed.]

Brain Puncture.—A wheal is made at the point of the contemplated puncture and an injection of a few cubic centimeters of a 0.5 per cent novocaine-suprarenin solution is made beneath this wheal.

Extirpation of Atheromata.—Two points for injection are chosen which correspond to the ends of the proposed line of incision (Fig. 41). From these points injections are made in a rhombic or quadrilateral form,

injecting 10 to 30 cc of a 1 per cent novocaine-suprarenin solution in the direction of the dotted line.

FIG. 41.—Anesthesia for an atheroma of the skull.

FIG. 42.—Circuminjection of a complicated fracture of the skull.

Methods to be Used in Extensive Injury of the Soft Parts, or Complicated Fractures of the Skull.—In the neighborhood of the injury a

number of points of entrance are marked by wheals which completely surround the operative field. As shown in Fig. 42, seven points are made. They should not be farther separated from one another than the curvature of the skull will permit in connecting these points with a straight needle beneath the fascia. From these points the loose subfascial tissue should be injected in the form of a narrow line completely surrounding the operative field in the direction indicated by the dotted line and infiltrated with a 1 per cent novocaine-suprarenin solution. After the injection the skin of the injected strip is raised in the form of a narrow wall above the surface of the surrounding skin. In one or two minutes, however, this elevation disappears. About 5 cc of this solution should be injected to each 5 cm. of the proposed line of injection. In this instance about 40 cc of a 1 per cent novocaine-suprarenin solution will be necessary. In all cases the line of circuminjection must be so made that all accessory incisions, whether for the purpose of enlarging the wound or for the plastic closing of defects, will be included within this area before beginning the operation. The anesthesia of this operative field is complete after a few minutes.

In very severe head injuries, in which the patient is comatose, anesthesia of any sort is unnecessary, while in those partially conscious it may at times be necessary to use light general anesthesia in addition, but even in these cases we use the method of circuminjection on account of the bloodlessness of the operative field. For the repair of the majority of head injuries general anesthesia is unnecessary.

Extirpation of a Rodent Ulcer of the Scalp with Resection of the Skull.—In this case the tumor was removed along with a section of bone $7\frac{1}{2}$ cm in diameter; the dura was, as usual in this region, insensitive. Fig. 43 shows the patient after healing; the skin defect was covered by epithelial grafts. This operation was done in 1905 in the days of cocaine anesthesia, and was probably the first resection of the skull performed under local anesthesia. The circuminjection as shown in the figure was carried out from six points 30 cc of a 0.2 per cent cocaine solution with 0.1 mg. of suprarenin were used. At the present time 30 to 50 cc of a 1 per cent novocaine-suprarenin solution would be used.

Extensive Resection of the Skull with Repair of the Dura and Plastic Skin Flap.—The case was one of a large sarcoma of the right side of the roof of the skull, springing from the periosteum and adherent to the skin (Fig. 44). This large defect after the extirpation was covered with a pediculated skin flap taken from the left side of the occipital region; no attempt was made to replace the bone. For this purpose the entire roof of the skull was surrounded by a line of infiltration, only half of the points for injection and line of injection being shown in Fig. 42. Above the zygoma and in the occipital region the parts were injected not only subcutaneously but also intramuscularly, as will be more fully described in the next case; 75 cc of a 1 per cent novocaine-suprarenin solution were used.

This operation, which was performed in 1911, was painless and free from an appreciable loss of blood. The skin surrounding the tumor was

incised and the bone in the same area was outlined with Borchardt's forceps; the dura was finally excised, as it was found to be adherent to

FIG. 43. –Circuminjection for resection of the skull for rodent ulcer.

FIG. 44.—Sarcoma of the skull, showing half of the circuminjection figure. The other half includes the flap used for plastic repair of defect.

the tumor. As usual, the excision of the dura in the temporal region above the zygoma caused slight pain, whereas its separation from the upper portion of the skull was absolutely insensitive. Fig. 45 shows the tumor

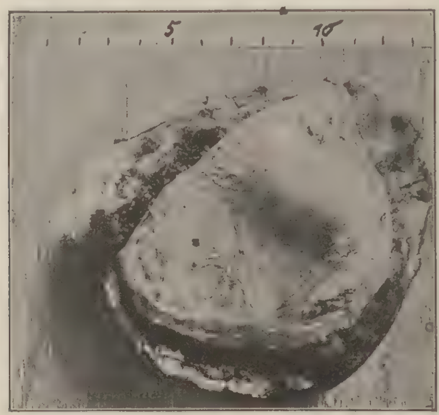


FIG. 45.—Sarcoma of the skull, showing section after removal.

FIG. 46.—Sarcoma of the skull, showing patient after removal of the tumor.

with the resected portion of the dura adherent to it. Fig. 46 shows the patient after removal of the tumor. The flattening of the exposed surface of the brain due to the pressure of the growth is easily observed. Fig. 47 shows the patient with the skin flap ready to be placed in position.

This was done after the defect in the dura was closed by a piece of the fascia lata, which was also removed under local anesthesia. The patient is sitting upright on the operating-table unaided, save for the head, which is being held by an assistant for the purpose of being photographed. The operation was concluded by sewing the skin flap in the defect of the right half of the scalp, and covering the secondary defect by epithelial grafts taken under local anesthesia.

Fig. 48 shows the patient after healing, which occurred by primary intention, with the exception of a small marginal area of the transplanted

FIG. 47.—Sarcoma of the skull, after transplantation of fascia for covering the defect in the dura, and the skin flap separated.

flap which became gangrenous. Although the transplanted piece of fascia was exposed to the air for a time it nevertheless retained its vitality and became covered with epithelium. The photographs show that the hemorrhage was very slight owing to the use of local anesthesia.

Resection of the Skull in the Temporal Region.—The author has frequently performed operations in this region, usually for the purpose of removing an epidural hematoma, and once for the removal of a foreign body which lay exactly in the center for speech, after which the motor aphasia disappeared. Everyone of these operations demonstrated the

Fig. 48.—Sarcoma of the skull, showing patient after healing.

Fig. 49.—Wheals marking the points for injection and the location of the skin incision for resections of the skull in the temporal region.

fact that the dura toward the base was distinctly, if only slightly, sensitive to pain. Fig. 49 shows the arrangement of the wheals and the circuminjection figure used in the excision of a bone-muscle flap in the temporal region. Point 1 lies in the middle of the upper border of the zygoma and from this point a 0.5 or, better, a 1 per cent novocaine-suprarenin solution is injected not only subcutaneously in the direction of the dotted line indicated in the diagram but also transversely, the line of infiltration extending through the temporal muscles, according to Fig. 50. The figure shows schematically a transverse section through the skin, temporal muscle and temporal bone made from wheal 1; this line corresponds to the upper border of the zygoma and parallel with it. From point 1, the needle is first inserted perpendicularly to the skin surface until it reaches the bone (arrow 1), then in a more oblique direction toward the anterior and posterior edge of the temporal muscle, until bone is again felt (arrow 2). The injections are all made in the same horizontal plane. Finally, the last injection is made beneath the subcutaneous connective tissue (arrow 3) toward points 2 and 6 (Fig. 49). For the injection from point 1,

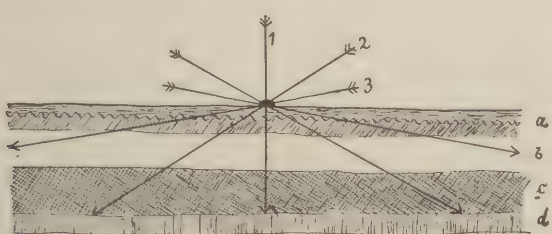


FIG. 50.—*a*, skin; *b*, subcutaneous connective tissue; *c*, cross-section of the temporal muscle; *d*, temporal bone.

about 30 cc of the solution are necessary; for the subcutaneous circuminjection of the operative field another 30 cc. Therefore at least 60 cc of novocaine-suprarenin solution are necessary for the entire injection.

Krause has recently reported the excision of the Gasserian ganglion under local anesthesia, with the patient previously prepared by the administration of pantopon-scopolamine. It is advisable in this operation not only to circuminject the field of operation but also to block the mandibular nerve in the foramen ovale or to inject the Gasserian ganglion direct, according to the method of Haertel. This method will scarcely require further consideration, as it is possible to reach the trunk of the trigeminus at its point of exit, or puncture the ganglion direct, after which alcohol is injected, which destroys the ganglion without extirpating it.

Exposure of the Cerebellum.—The author has performed this operation eight times[1] under local anesthesia without causing any pain whatever. Like success was also noted in two previous case reports. The simultaneous suprarenin anemia is of the greatest importance in these operations, as

[1] To 1913.

it makes it unnecessary to postpone opening the skull until a subsequent time. Fig. 51 shows the arrangement of the points for injection and the line of incision for the exposure of both hemispheres of the cerebellum. It is advisable not to depart from the arrangement as shown in the diagram even if only half of the cerebellum is to be operated upon. The points 3 and 9 lie immediately back of the base of the mastoid process. From these two points, as well as from the points 1, 2, and 10, the necessary injections are made into the muscles of the neck. The object of these injections is to infiltrate the muscle layers with suprarenin solution in a

FIG. 51.—Wheals marking the points for circuminjection for exposure of the cerebellum.

cup-shaped manner, which isolates the operative field from the rest of the body. The operative field itself is not injected. The direction of the needle in this injection is analogous to that of the temporal muscles (Fig. 50). The needle-point must always be inserted as far as the transverse processes of the cervical vertebræ and the occiput. The connections of the various points of injection are made subcutaneously. It will be necessary to use between 100 to 120 cc of solution, more than half of which is used for the injection of the muscles of the neck. The 0.5 per cent novocaine-suprarenin solution will cause complete anesthesia and anemia. The dura of the posterior fossa of the skull, which the author thought

from his early experience to be insensitive, was found in the last 2 cases of tumor of the cerebellum operated on by him to be clearly and in 1 case indeed quite sensitive to pain both on pinching and cutting. The cerebellum itself as all other parts of the brain is insensitive.

In resections of the skull under local anesthesia the use of the chisel should be limited as far as possible, as its manipulation is very unpleasant to the patient. The use of morphine, pantopon-scopolamine, etc., in patients with brain injuries and affections causing pressure should be avoided owing to the unfavorable action on the respiratory center. If the operator confines himself to the use of the saw and bone forceps, patients do not complain of skull and brain operations carried out under local anesthesia. The psychic condition of the patient must always be taken into consideration. At times it is desirable to induce light general narcosis.

Bier has recently reported operations on the cerebrum under local anesthesia. He found that the irritability of the cortex was diminished even though the injections were made on the outer surface of the skull. If this observation proves to be correct, local anesthesia will not be suitable in operations for epilepsy.

OPERATIONS UPON THE ORGANS OF HEARING.

The external ear is innervated by the auricularis magnus, auriculotemporalis, occipitalis minor, and the auricular branch of the vagus. The bony canal of the ear and its lining as well as the outer surface of the drum are innervated by branches of the auriculotemporalis and the auricular branch of the vagus which pass from in front and from behind at the junction of the soft parts and bony canal into the organs of hearing. The inner surface of the drum, the mucosa of the antrum, epitympanic recesses, and the Eustachian tube are innervated by the tympanic branch of the glossopharyngeal nerve. The mucous membrane of the mastoid cells and of the antrum of the tympanum is innervated by the nervus spinosus, a branch of the mandibular, which passes from the cranial cavity through the petrosal fissure into the temporal bone.[1]

Anesthesia of the Membrana Tympani.—The ear-drum reacts but slightly to anesthetic agents (cocaine or alypin) applied to its surface, owing to its protective epidermis. Applications of carbolic acid are much more effective (Bonain), or a combination as recommended by Hechinger can be used, which consists of acid. carbol. 0.5, cocaine muriat. menthol āā 2, alcohol 10. This solution is applied to the drum and external canal by means of small tampons after which paracentesis and incision of furuncles can usually be made without pain. Tiefenthal, for anesthetizing the drum for paracentesis, injected 2 to 4 drops of a 5 to 10 per cent cocaine-suprarenin solution with a fine needle into the tympanic cavity. Albrecht used cataphoresis for anesthesia of the drum. He

[1] It is impossible for the author at this time to consider extensively anesthesia in connection with the so-called special operation, as he has not had sufficient personal experience.

saturated a cotton applicator, attached to the positive electrode with a 20 per cent cocaine solution, and applied it to the drum. After three or four minutes it was insensitive.

Anesthesia of the External Auditory Canal.—Complete anesthesia of the external auditory canal can easily be obtained by an injection of the anesthetic near the bone, both in front of and behind the canal, as recommended by Eicken and Laval. By means of this injection the vagus and auriculotemporalis, which supply the auditory canal, are blocked. The point for injection lies in front of the tip of the mastoid behind the attachment of the ear. The lobule is drawn forward and outward, the needle is then directed along the anterior surface of the mastoid process, passing the auditory canal, to the temporal line; 1 or 2 cc of a 2 per cent novocaine-suprarenin solution are injected. The needle is then passed in a line near the front of the auditory canal and back of the maxillary articulation as

FIG. 52.—Van Eicken's injection for anesthesia of the auditory canal.

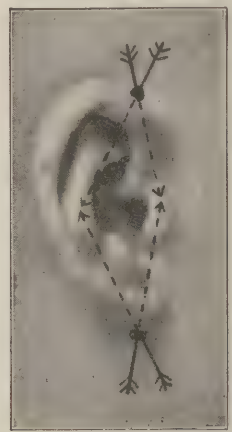


FIG. 53.—Anesthesia of the pinna of the ear.

far as the junction of the zygoma with the temporal bone (Fig. 52). In making the anterior injection, Eicken and Laval recommend that the mouth be open, so that the head of the inferior maxillary bone will be pushed forward. Sensation in the drum will be diminished after this injection but not entirely lost.

Anesthesia of the External Ear.—By means of a subcutaneous injection carried out from two points around and under the attachment of the ear (Fig. 53), using about 20 cc of a 0.5 or 1 per cent novocaine-suprarenin solution, the entire external ear may be rendered insensitive.

Anesthesia of the Tympanic Cavity.—In case of destruction of the drum the mucous membrane of the tympanic cavity can be anesthetized by dropping into the ear a few drops of a 10 to 20 per cent solution of cocaine or alypin. The complicated shape of this cavity makes it difficult to obtain an even distribution of the anesthetic which not infrequently

interferes with complete anesthesia. Tiefenthal's injection through the unruptured drum has already been mentioned. Neumann claims that if fluid be injected beneath the upper wall of the external auditory canal the soft parts will be separated from the bone and the fluid must pass under the drum membrane and the mucous membrane of the tympanic cavity, and in this manner cause both the drum and the tympanum to become completely anesthetized.

Neumann has described this injection as follows: The needle is passed through the cartilage and beneath the periosteum of the upper wall of the external auditory canal about 0.5 to 1 cm. from the beginning of the bony part. This point of injection can be readily determined by moving the ear up and down, the cartilaginous portion forming a fold where it adjoins the bony part. Another means of distinguishing this boundary is the difference in appearance between the cartilaginous and the bony part of the canal. The former appears dull, while the latter is glossy. After fixing the point for injection the needle is passed in an oblique direction upward until the bony canal is felt; the anesthetic solution is then injected under medium pressure. It will be necessary to wait about ten minutes before anesthesia is complete.

The method of Neumann has been used with marked success in Politzer's clinic for operations upon the internal ear, as in the removal of the hammer and anvil, etc. Gompertz, Thies, Halacz, Bárány, Harley, and others, have stated that a very satisfactory anesthesia of the drum and tympanic cavity can be obtained by means of the Neumann injection in combination with the application of strong anesthetics.

The Chiselling of the Mastoid Process, Opening of the Tympanic Cavity and the Radical Mastoid Operation.—We will now consider the most extensive of these operations, which will suffice for all the minor operations in this region. The attempts of Alexander to perform the radical mastoid operation by means of Schleich's infiltration anesthesia has not found many followers. It was through the work of Neumann that progress was made in this direction. His method consisted in the circum-injection of the external auditory canal, as already described by Eicken and Laval, combined with anesthesia of the drum and tympanic cavity by means of the Neumann injection, thus producing complete anesthesia of the external ear, the soft parts overlying the bone and the internal ear. Kulenkampff used this method in his series of 30 radical operations. The author has also used this method and can state that the results have been very good in cases in which the above-mentioned technic has been carried out. He also recommends the following procedure, which in principle has been suggested by Neumann:

With the patient's head lying on the healthy side, begin by instilling a few drops of a 20 per cent alypin or cocaine solution with the addition of suprarenin into the external auditory canal. Inasmuch as the drum is usually destroyed, the solution itself enters the tympanic cavity and can act upon the mucous membrane during the subsequent proceedings. Beyond this cocaine is unnecessary.

The circuminjection of the entire operative field is carried out from 3 or 4 points as shown in Fig. 54. It will be necessary to use 40 cc of a 0.5

Fig. 54.—Circuminjection of the operative field for the radical mastoid operation.

per cent novocaine-suprarenin solution for this injection, more than half of which should be used along the lower border of the operative field in the region of the occipital and great auricular nerves. Injections in the line

Fig. 55.—Appearance of the operative field for the radical mastoid operation immediately after injection.

of incision, as recommended by Neumann, are not necessary. The photograph, as shown in Fig. 55, was made immediately after the injection and

shows this surface raised above the surrounding skin; this condition disappeared within a few minutes. It will now be necessary to anesthetize the auditory canal, which is done in the following manner: With the ear drawn forward, a point of entrance is marked just behind the ear (Fig. 56), the needle is passed along the anterior surface of the mastoid process as far as the bony canal, and 2 cc of a 2 per cent novocaine-suprarenin solution injected. This injection requires considerable pressure, for which reason the solution will be evenly distributed around the entire canal. This is followed by the previously described Neumann injection (2 cc of a 2 per cent novocaine-suprarenin solution) in the upper wall of the canal. The latter is painless because the canal has already been rendered insensitive. It is also necessary to make an injection of 1 to 2 cc of a 2 per cent novocaine-suprarenin solution from within, along the anterior wall of the canal.

Fig. 56.—Position of the point of injection back of the auditory canal.

If this injection has been properly made, the incision of the soft parts, the separation of the periosteum, the separation of the membranous portion of the canal from the bony portion, and any plastic incisions will be absolutely painless. Following the suggestion of Dr. Kulenkampff the latter incision should be completed before beginning the operation on the bone, which permits a much better approach to the rest of the field of operation. If a traction suture is passed through the membranous part of the canal, after its incision, the ear and canal can be easily held forward without the aid of hooks. The chiselling of the mastoid process and the opening of the antrum are entirely free from pain. In fact these parts do not seem to be possessed of marked pain sense. Anesthesia of the tympanic cavity may be imperfect and it may be necessary, after the separation of the membranous canal, to apply a 20 per cent alypin or cocaine-

suprarenin solution to the mucous membrane. The region of the tube nearly always remains sensitive. The anemia of the operative field is of marked advantage in this operation, and makes possible the previously mentioned plastic incision at the beginning of the operation. The drawback to this method of operating is the very unpleasant sensation to the patient from the use of the chisel. If the surgeon selects his cases, excluding the nervous and excitable ones, he will find that the majority of radical operations can be carried out with perfect satisfaction to both the patient and the operator if morphine or morphine-scopolamine precedes the anesthetic.

The opening of the mastoid process and the antrum under local anesthesia was attempted before this method was tried for the radical operation (Reclus, Schleich, Scheibe, Thies, Alexander, Neumann). Inasmuch as these cases usually belong to the acute septic type, it is well to consider carefully the advisability of injecting into such an operative field. According to the author's judgment there must be very definite conditions contraindicating the use of general anesthesia before local anesthesia should be attempted. At any rate this method of anesthesia will be used much more frequently in the radical operation than in cases of acute otitis. In perforation of phlegmonous suppurations these injections are not permissible.

For the opening of the antrum the Neumann injection is not necessary, and the operator should proceed as in the radical operation. For the simple opening of the mastoid cells, infiltration of the soft parts is sufficient.

Attempts have been made to block the glossopharyngeal nerve at the base of the skull by injections through the mouth, but without result. However, Hirschel has apparently succeeded in blocking the glossopharyngeal and vagus by means of an injection between the condyle of the lower jaw and the mastoid process. Whether it will be possible to block the upper branches supplying the organs of hearing remains to be seen.

Blocking of the Trigeminus Nerve.—The blocking of one or more branches of the trigeminus nerve is necessary in nearly all operations upon the face which are not confined to the skin or subcutaneous tissue. The blocking can be carried out, according to the demands of the operation, either at the points of exit of the nerve trunks at the base of the skull in the course of one or more of their branches or intracranially in the Gasserian ganglion itself.

Anesthesia of the trigeminus nerve in the foramen rotundum at the base of the skull was first performed by Matas. Bockenheimer, at the suggestion of Payrs, later carried out this procedure. These first attempts sought no further practical results and could not because of the lack of a suitable local anesthetic. Blocking of the branches of the trigeminus nerve as a definite procedure was first worked out by the author and the first contribution and description of several operations upon the face was published by his assistant, Peuckert. The method has since been materially improved following the introduction by Schloesser of alcohol injections

in the treatment of trigeminal neuralgia and by the work of Haertel. We are indebted to Offerhaus for his important communications in reference to the technic of injection of the third branch of this nerve. He devised his method independently, following his experiments with alcohol injections. He likewise used anesthetic substances to render operations painless.

For the central trigeminus injection the long, thin needles Nos. 5 and 6 (page 180) should be used. The needleholder as shown in Fig. 19 will be found very helpful with needles of this length.

Ophthalmic Nerve.—The peripheral branches on the forehead are easily reached by a subcutaneous injection of 5 to 10 cc of a 1 per cent novocaine-suprarenin solution made transversely above the eyebrows. Fig. 57 shows the extent of the anesthesia following this injection. The area of this anesthetic field is quite variable and the principle as previously laid down should always be followed, that in operations upon the forehead and scalp, large operative fields should always be circuminjected.

Fig. 57.—Extent of absolute anesthesia after blocking the frontal branches of the ophthalmic nerve.

The trunk of the ophthalmic nerve cannot be directly injected, inasmuch as it usually divides into its branches, the lacrimal, frontal, and nasociliary, before entering the orbit. The nasociliary passes through the annulus tendineus into the apex of the orbit and innervates the eye (Fig. 58). Its two branches, the ethmoidal nerves, leave the apex of the orbit and pass into the anterior and posterior ethmoid foramen. The frontal and lacrimal lie entirely outside of the apex of the orbital wall, and like the ethmoidal nerves are inaccessible to injections in the posterior portion of the orbit.

The walls of that portion of the orbit which are straight and not concave are particularly suitable for injection, and serve as a guide for the needle to the orbital apex beyond the muscular covering, keeping the needle in constant contact with the bone. These conditions are found along the lateral walls and the upper portion of the median wall of the orbit. In other places where the point of the needle cannot be held in

contact with the bone there is always danger of injury to the eyeball. The use of curved needles cannot be recommended, as the exact location of the point is never known. The lateral point of injection lies immediately

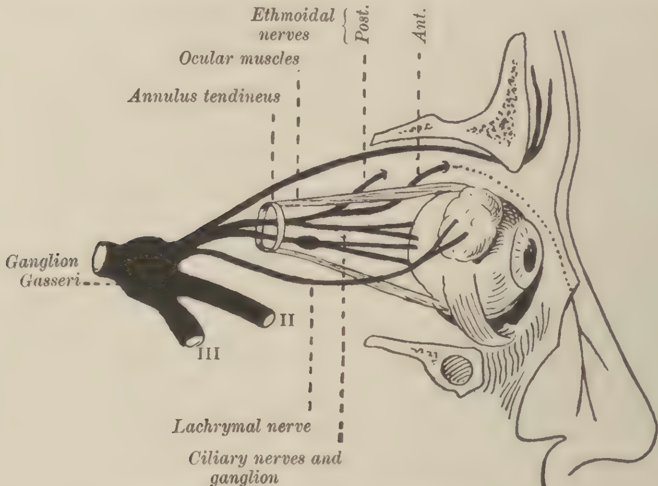


Fig. 58.—Diagrammatic course of the ophthalmic nerve. (After Corning.)

above the outer canthus of the eye. The needle is passed with its point constantly in contact with the bone to a depth of 4.5 to 5 cm., and here crosses the superior orbital fissure (Fig. 59). The point encounters the

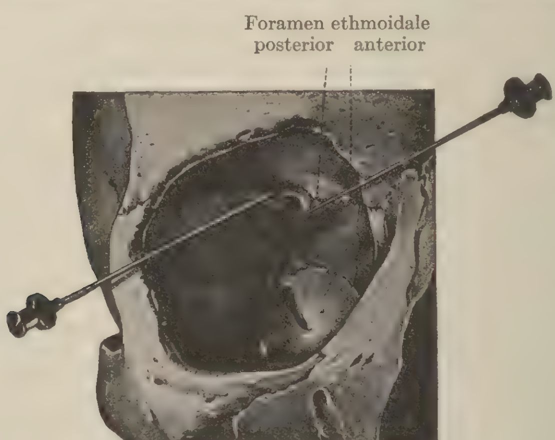


Fig. 59.—Median and lateral orbital injections.

distal border of this fissure in the upper wall of the orbit which prevents its further introduction. About 2.5 cc of a 2 per cent novocaine-suprarenin solution is injected in the neighborhood of the superior orbital fissure.

The point of entrance for the median orbital injection lies one finger-breadth above the inner canthus of the eye. The needle is again passed to a depth of 4 to 5 cm, keeping it at all times in contact with the bone, and the same quantity of solution injected at this point.

The lateral orbital injection blocks the frontal and lacrimal nerves which is necessary in operations in the orbit and frontal sinuses. The frontal nerve and its branches can likewise be blocked farther forward in the orbit by injections made above the bulb.

The median orbital injection blocks the anterior and posterior ethmoidal nerves which supply the mucous membrane of the cribriform plate of the ethmoid, frontal, and sphenoid sinuses. Besides these parts the anterior ethmoidal nerve supplies a portion of the nasal mucous membrane (Figs. 86 and 87), and then passing from the nose at the junction of the cartilaginous and bony part is distributed in the skin of the tip of the nose and its surroundings (Fig. 40). The median orbital injection is, therefore, necessary in operations upon the nasal cavities and other accessory sinuses.

After the injection a mild, transient protrusion of the bulb and edema of the upper lids occur. The injections into the orbit cause very little pain if the points for injection are first made insensitive by means of a wheal. The injected fluid is entirely outside of the muscular boundaries of the orbit, for which reason the sensory nerve of the bulb, ciliary nerves, ciliary ganglion and the optic nerve are not, as a rule, affected. If the nerves just mentioned are to be anesthetized the solution must be injected behind the bulb and within the muscle boundaries of the orbit (see page 238).

Serious disturbances following orbital injections have not been seen by the author and injury to the bulb is practically impossible. Small hematomata occur occasionally in the orbital fat, particularly following the lateral injections, but are of no consequence. Kredel observed amaurosis lasting ten minutes, following an injection into the orbit. It is possible that this occurrence may have been more frequently observed than reports indicate, inasmuch as the optic nerve can be affected by the anesthetic as well as by the anemia consequent upon the use of suprarenin. Another case of temporary amaurosis following local anesthesia for empyema of the frontal sinuses has been reported by Jassenetzky. This condition occurred on the day following the operation and was due to an inflammatory edema of the orbit, and inasmuch as the case was a septic one, it is very questionable whether the injection had anything to do with the inflammatory symptom.

Maxillary Nerve.—The peripheral branches of this nerve are the infraorbital, superior, posterior, and median alveolar nerves. The latter penetrate the upper jaw posteriorly to the maxillary tubercle (see Fig. 102, page 262). Both of these branches are readily blocked.

The infraorbital foramen can be reached by passing a needle beneath the upper lip where the submucosa is reflected from the alveolar process along the anterior surface of the upper jaw to the point of emergence of this nerve, or better, by passing the needle from without directly into the

infraorbital foramen. The injection after either method is 2 cc of a 2 per cent novocaine-suprarenin solution. When passing the needle from without into the infraorbital foramen, a fine one should be used and inserted just beneath the lower orbital border and passed until it touches the bone, where a small quantity of a 2 per cent novocaine-suprarenin solution is injected, following which the opening of the canal is sought with the needle. The injection of 1 cc of a 2 per cent solution is sufficient for blocking the nerve. Fig. 60 shows the extent of the anesthesia following a bilateral injection. The following structures are anesthetized: The lower eyelids, the upper lip, the larger part of the alæ of the nose (skin and mucous membrane), a part of the skin and mucous membrane of the cheek, the labial mucous membrane, the anterior portion of the upper alveolar process and its periosteum, the anterior wall of the upper jaw and the pulp of the central and lateral incisor and canine teeth.

Fig. 60.—Extent of skin anesthesia following a bilateral injection into the infraorbital foramen.

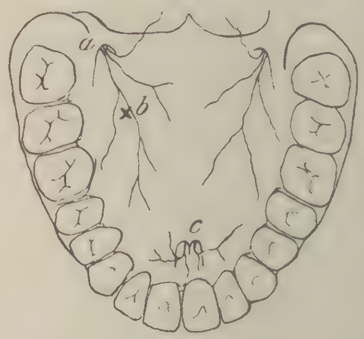


Fig. 61.—Innervation of the hard palate: *a*, ant. palatine nerve; *b*, point for injection; *c*, nasopalatine nerve. (Scarpa.)

The superior, posterior, and median alveolar nerves are easily injected at the maxillary tubercle either from the mouth or from without. With the former method the needle is passed beneath the zygoma, where it joins the superior maxillary bone beneath the mucous membrane to the posterior border of the upper jaw (see Fig. 104). The method of directing the needle from without will presently be described and is the same as used for injections of the foramen rotundum, only it is not necessary to pass the point of the needle into the pterygopalatine fossa. In either case 5 cc of a 1 or 2 per cent novocaine-suprarenin solution is injected along the posterior border of the upper jaw, which produces anesthesia of the pulps of the molar and bicuspid teeth and mucous membrane of the antrum of Highmore.

The nerves supplying the hard palate can be readily interrupted by peripheral injections. These nerves are the anterior palatine and the nasopalatine. The former emerges from the foramen palatinum magnum in the neighborhood of the third molar tooth, and the latter from immedi-

ately behind the incisor teeth (Fig. 61). If a few drops of a 2 per cent novocaine-suprarenin solution be injected beneath the covering of the hard palate back of the left central incisor, followed by 1 to 2 cc of the solution injected at the point marked *b* (Fig. 61), which is about 1 to 1.5 cm. from the gum-line and internal to the second molar tooth, anesthesia of the corresponding half of the hard palate and its soft parts, the lingual side of the gums and the periosteum, will be obtained. The roots and pulp of the teeth in this neighborhood are not anesthetized by injections into these nerves.

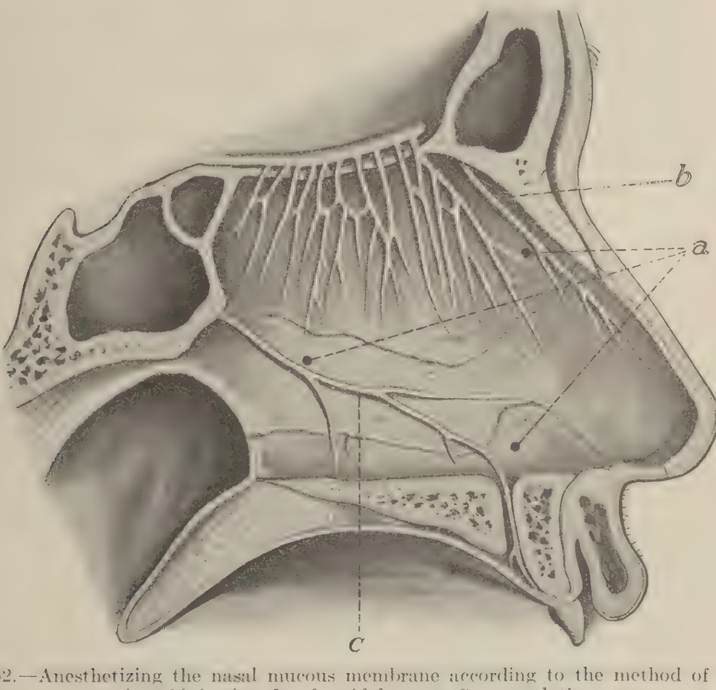


Fig. 62.—Anesthetizing the nasal mucous membrane according to the method of Killian. *a*, point of injection; *b*, ethmoidal nerve; *C*, nasopalatine nerve.

Killian, by injections under the mucous membrane near the upper border of the vomer and upper border of the septum (Fig. 62), has attempted to anesthetize the peripheral branches of the first and second divisions of the trigeminus (ethmoidal and nasopalatine).

Matas was the first to attempt to anesthetize the maxillary nerve in the foramen rotundum. Before the introduction of suprarenin this was not possible owing to the large dose of cocaine necessary for a protracted operation. His method was to pass the needle beneath the lower border of the zygoma and along the posterior surface of the upper jaw into the pterygopalatine fossa, which is simple and certain. This method was likewise used by Schloesser for the injection of alcohol. Fig. 63 shows the position of the bony parts and Fig. 64 the position of the needle after

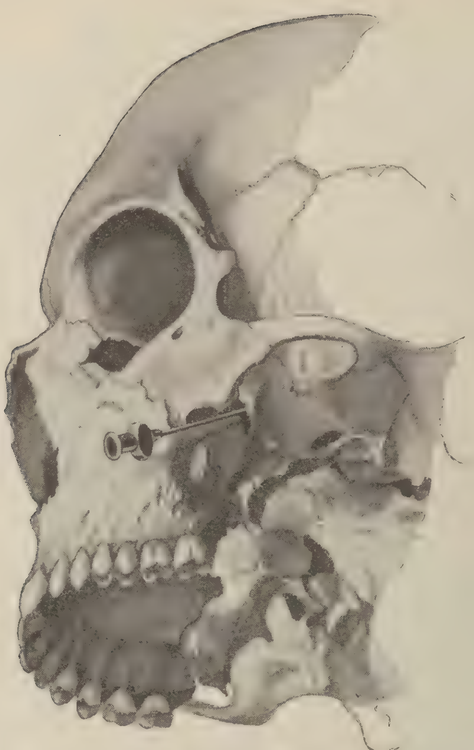


Fig. 63. Injection of the foramen rotundum from without.

Fig. 64.—Injection in the foramen rotundum from without, showing the cork guide on the needle. The patient has a large root cyst of the left lower jaw and a similar cyst of the right upper jaw. This injection is being made for operation upon the latter.

introduction through the face. The point of insertion of the needle lies immediately behind the lower palpable angle of the malar bone and is marked by a wheal. From this point the needle is pressed inward and upward; its point passes through the masseter muscle and then comes in contact with the superior maxillary tubercle and is forced carefully along the surface of this bone. The needle-point will occasionally strike the wing of the sphenoid, in which case the direction of the needle must be slightly changed or, if necessary, withdrawn entirely and another point of entrance made just back of the middle of the zygoma. The needle will then suddenly pass deeper into the pterygopalatine fossa and reach the nerves at a depth of 5 to 6 cm. At the same moment the patient will complain of radiating pain in the face, after which 5 cc of a 2 per cent novocaine-suprarenin solution is injected, moving the needle back and forth slowly. The needle is then partially withdrawn and 5 cc of 0.5 to 1 per cent novocaine-suprarenin solution is injected back of the upper jaw to cause a contraction of the branches of the internal maxillary artery.

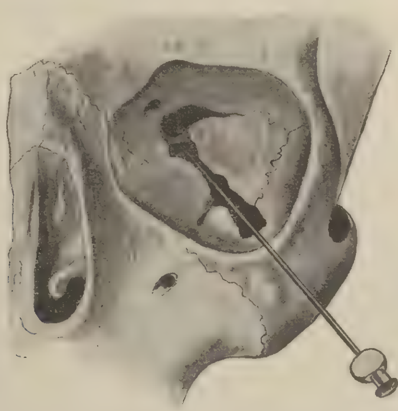


FIG. 65.—Injection at the foramen rotundum through the orbit.

The foramen rotundum may be reached by injections through the orbit (Fig. 65). Payr, after experimenting on the cadaver, advised this method in resections of the upper jaw.[1]

Upon Payr's suggestion, Bockenheimer anesthetized the second branch of the trigeminus and resected the same for neuralgia. During the past year the writer has used the orbital method in operations upon the teeth and antrum of Highmore, likewise for alcohol injections. The method is as follows: A point is chosen for injection where the lower edge of the orbit meets the outer edge. The needle is passed into the orbit at this point in an almost vertical direction and kept in constant contact with the bone forming the floor of the cavity (Fig. 66). The inferior orbital fissure

[1] The author regrets having overlooked the reports of Payr and Bockenheimer, which, however, do not seem to have been applied practically to any extent.

is now sought and recognized by the needle passing into it. As soon as this happens the end of the needle is lowered so that it will assume a horizontal position (Fig. 67), which prevents it passing into the infratem-

FIG. 66.—Injection at the foramen rotundum through the orbit.

FIG. 67.—Injection at the foramen rotundum through the orbit.

poral fossa or into the orbital fat, which is also to be avoided. A false passage will be recognized by the absence of resistance to the progress of the needle. This resistance always occurs when the proper direction is

taken and causes immediate radiation of paresthetic sensations which frequently require the injection of a few drops of the novocaine-suprarenin solution. At a depth of about 5 cm. the needle will be in the foramen rotundum and there encounter the bony obstruction at the base of the skull. Haertel gives the following directions for introducing the needle. With the left hand the eyeball is pressed upward while the needle is passed along the inferior orbital wall in the sagittal direction until it passes through the inferior orbital fissure and at a depth of 4 to 5 cm. it strikes against the anterior surface of the pterygoid process. By carefully feeling one's way with the point of the needle upward and inward, the nerve will be reached as made manifest by the appearance of paresthesias. The needle is correctly placed if when viewed from the front it points to the upper and inner angle of the orbit and viewed from the side it points to the upper border of the ear. Offerhaus mentions a third way of reaching the nerve, which is also recommended by Payr for alcohol injections. The point of entrance of the needle lies just above the zygoma, according to Offerhaus in the middle of the zygomatic arch, according to Payr at the angle formed by the lateral wall of the orbit and the upper border of the zygoma. According to Haertel's investigations a needle passed in above the zygoma will enter the pterygopalatine fossa in only 12 per cent of the cases.

After a successful injection, anesthesia will immediately occur in the entire area of distribution of the maxillary nerve. Injections which have been only partially successful require ten to twenty minutes before the full effect is obtained. After these injections the corresponding half of the face becomes anemic in consequence of the action of the suprarenin on the end branches of the internal maxillary artery.

One of the secondary effects which may follow injection into the pterygopalatine fossa, besides small hematomata on the posterior surface of the upper jaw, is paralysis of the muscles of the eye, particularly the oculomotor nerve, due to the needle occasionally passing through the inferior orbital fissure into the orbit. This paralysis disappears with the return of sensation. Although the dangers following injections for purposes of anesthesia are slight, one must be particularly careful with alcohol injections. Alcohol must never be introduced until after the nerve has been blocked with anesthetics in order to determine the absence of these secondary effects on the muscles of the eye.

Injection through the orbit does not cause paralysis of the muscles of the eye, inasmuch as the needle passes into and then entirely out of the orbit, for which reason alcohol injections can be made much more safely by this route. Hematomata on the floor of the orbit and in the upper lid occasionally occur after orbital injections.

Mandibular Nerve.—There are two methods of injection for the third branch of the trigeminus, both of which are certain and bring about a rapid blocking of the nerve. The first consists in interrupting the inferior alveolar and lingual nerves by injection on the inner surface of the lower jaw into the region of the lingula; the other consists in blocking thenerve trunk in the foramen ovale.

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open the operator introduces the index finger of the left hand and locates the anterior border of the coronoid process and the "trigonum retromolare." The syringe and needle are held in the manner shown in Fig. 70 and remain in this position during the entire procedure. The needle is directed from the opposite lower canine toward the point of injection and held parallel to the biting surface of the lower teeth. The needle is inserted at the above-mentioned point 1 cm. above and lateral to the biting surface of the last molar tooth into the "trigonum retromolare." Immediately under the thin mucous membrane the bone should be felt. If this is not the case, the point of the needle is too far from the median line, a mistake frequently made by beginners. In this case the needle must be directed toward the median line until the border *a* (Fig. 68) is felt. The

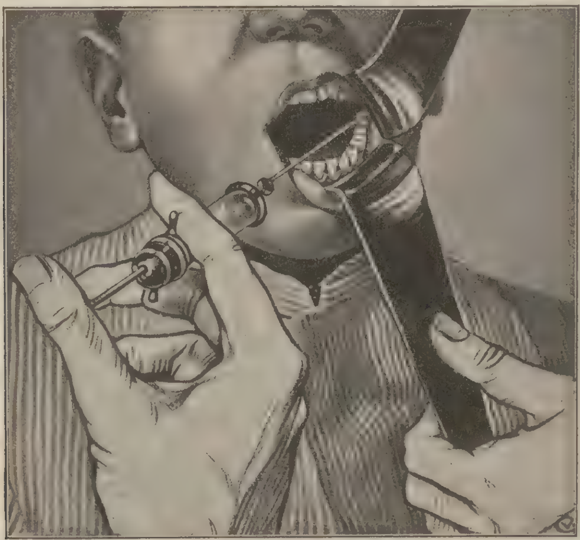


FIG. 70.—Injection at the lingula, showing the position of the syringe.

needle finally passes along the inner surface of the lower jaw into the deeper parts. It must now be further inserted to a depth of 2 to 2.5 cm., keeping it always in contact with the bone. As soon as the needle begins to penetrate the region where the lingual nerve lies, 5 cc of 1 to 2 per cent novocaine-suprarenin solution should be injected.

Proceed with the injection, as shown in Fig, 70, using long needles, so that the discomfort occasioned by the introduction of the syringe into the mouth can be avoided. In no case should needles be so short that they can be lost to view during the injection, as it is a very difficult matter to remove a broken needle from this area. The interruption of both nerves occurs as a rule in a few minutes and can be tested by the loss of sensation in the lower lip, the tongue, and the floor of the mouth.

Schloesser, for the injection of alcohol into the inferior alveolar nerve,

passes a curved needle from without just under the end of the mastoid processes around the joint of the lower jaw to the lingula. The writer has had no experience in the use of this method, and does not believe that the lingual nerve will be interruppted with an injection of this kind. Gadd makes the injection with a straight needle from the inferior border of the lower jaw.

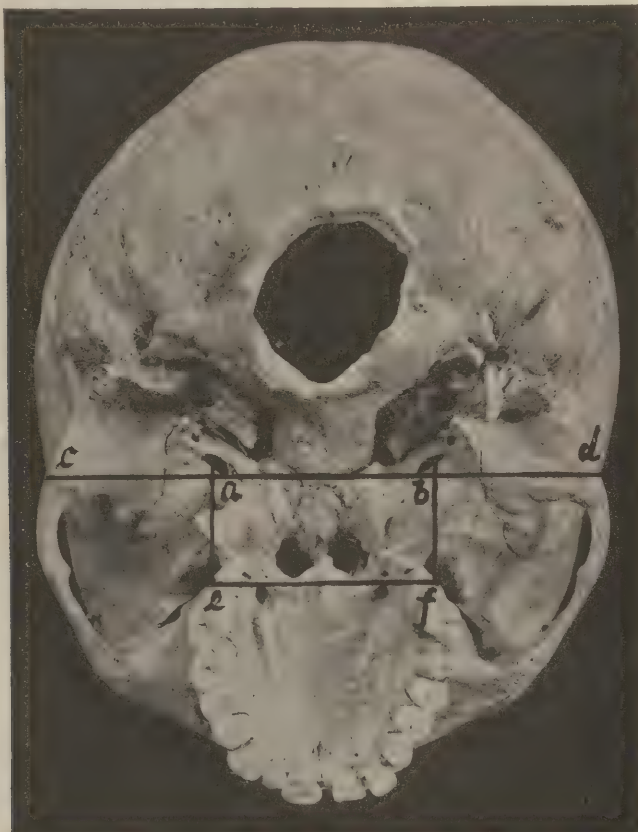


Fig. 71.—Skull measurements, according to Offerhaus, for the determination of the foramen ovale from the tuberculum articulare.

It is sometimes necessary to interrupt the end branches of the inferior alveolar nerve, the mental nerve. This can be accomplished by the injection of a 1 to 2 per cent novocaine-suprarenin solution into the mental foramen which, as a rule, is below the space between the first and second bicuspid teeth.

The shortest and most certain way of reaching the foramen ovale is from without, the needle being passed just below the border of the zygoma, and if the directions of Offerhaus are followed there is almost absolute

certainty that the anesthetic solution will not only be injected around the foramen ovale but directly into the trunk of the mandibular nerve where it emerges from the skull.

Offerhaus found, after accurate measurement of 50 skulls, that the line (linea intertubercularis Fig. 71, *c*, *d*) connecting the articular tubercle lies just in front of the maxillary articulation, and intercepts the two points (*a* and *b*) which are just a few millimeters below and, as a rule, the same distance in front of both foramen ovale.

Inasmuch as the mandibular nerve after its emergence from the skull passes forward and downward, the intertubercular line crosses these nerve trunks exactly at the foramen ovale.

Fig. 72.—Compasses of Offerhaus.

Offerhaus also noted that the distance between the alveolar processes of the maxilla measured from the outside behind the last molar tooth (Fig. 71, *e*, *f*) corresponds within a few millimeters to the distance between both foramen ovale, so that if the width of the alveolar processes is subtracted from the length of the intertubercular line, and this result divided by 2, the result will give within a few millimeters the distance of points *a* and *b* from the articular tubercle of the same side. According to the measurements of Offerhaus the minimum distance would be 3.6 cm. and the maximum 4.7 cm., the usual distance being 3.7 to 4.3 cm. In order to find the direction and length of the intertubercular line on the living patient, Offerhaus constructed the apparatus shown in Fig. 72. If the points of this apparatus are placed on both articular tubercles, the direction of the intertubercular line is indicated by the adjustable points of the instrument, and the distance between both tubercles is measured on the sliding scale.

The injection is performed in the following manner: On the side where the injection is to be made, the articular tubercle is marked by a wheal and the point on the opposite side marked with a blue pencil. The distance between the outer side of the alveolar process of the maxilla behind the last molar teeth is measured with ordinary compasses, and with Offerhaus compasses the length of the intertubercular line is determined. For example, if these distances are 5 and 14 cm., the points *a* and *b* will be $\frac{14-5}{2}$ = 4.5 cm. distant from the point of insertion of the needle. A small

Fig. 73.—Guidance of the needle for injection at the foramen ovale: 1, according to Offerhaus; 2, according to Braun.

cork placed on the needle, about 1 cm. farther than the above-mentioned length will show how far the needle should be inserted and also allow for additional play. The needle, however, should never penetrate deeper than this. The Offerhaus compasses are again placed upon the head and the needle passed into the tissues in the direction indicated by the points on the compasses. The direction of the needle is indicated in Fig. 73, needle 1. Exactly at the point determined, the patient will complain of radiating pains in the lower jaw. As a rule, the resistance of the thick nerve trunk can be felt at the needle-point, and at times the needle can be pushed into this trunk. After the needle is in the nerve trunk a very

few drops of a 2 per cent novocaine-suprarenin solution are sufficient; if near the nerve trunk 5 cc of this same solution are injected. The blocking of the nerve often occurs instantaneously, but never requires more than five to ten minutes.

The author's description of the injection of the foramen ovale is somewhat simpler than the above: The point of entrance for the needle is marked just below the middle of the zygoma (Fig. 73, 2), and the needle inserted in a strictly transverse direction. This direction is easily determined by holding a skull with the direction marked by a sound alongside the head of the patient. At a depth of 4 to 5 cm. the end of the needle touches the bone, the pterygoid process (Fig. 73). In this injection the needle is about 1 cm. distant from the foramen ovale. This distance is marked on the needle with the movable piece of cork. The needle is then withdrawn as far as the subcutaneous connective tissue, and is passed back again at a slight angle to the same depth and possibly a few millimeters more. The characteristic radiating pains will then occur.

This last method can be further simplified by computing the depth at which the foramen ovale is found. As a rule the author combines both methods in directing the needle, but passes it somewhat more anteriorly than Offerhaus, feeling for the base of the pterygoid process. Then, as already mentioned, the needle is directed slightly backward and inserted 0.5 to 1 cm. more than the previously computed distance. The author has never seen hematomata or other secondary effects follow injections into the foramen ovale when made from without.

The methods described by Ostwalt and Schloesser for the injection of alcohol into the foramen ovale cannot be compared with the method just described for certainty and freedom from danger. In this method Ostwalt passes a long angular needle through the wide-open mouth behind the last molar tooth through the external pterygoid muscle, and, by using the external lamina of the pterygoid process as a guide, reaches the foramen ovale. Schloesser for like purposes locates with the finger in the mouth the lower end of the wing of the sphenoid, passing a long, straight needle through the cheek, coming out just below the finger in the mouth, and then through the mucous membrane and under the finger toward the wing of the sphenoid above, until the resistance of the base of the skull is felt. The needle-point must now lie a few millimeters in front of the foramen ovale.

Haertel has described a very exact method for directing the needle in puncture of the Gasserian ganglion, which is in part similar to Schloesser's. His method is likewise of great value in the interruption of the third branch of the trigeminus.

Puncture of the Gasserian Ganglion.—Frequently after the injection of anesthetic solutions, and almost regularly after alcohol injections into the trunk of the mandibular nerve in the foramen ovale, sensory paralysis takes place not only in the second branch of the trigeminus but the first is also affected. This can only be explained by the theory that the fluid injected into the nerve trunk is disseminated into the Gasserian ganglion.

Haertel[1] completed experiments begun by Schloesser, Ostwalt, Harris, and Offerhaus for the passing of the needle into the foramen ovale and Gasserian ganglion.

It is necessary in this technic to pass the needle as nearly parallel to the course of the mandibular nerve as possible. This has already been mentioned by Ostwalt and Schloesser, but Haertel avoids the possibility of infection by not passing the needle into the mouth.

Fig. 74 shows the position of the needle in the skull. A No. 6 needle, 9 to 10 cm. in length, should be used. About 3 cm. lateral to the corner of the mouth a wheal about the size of a dollar is injected, so that the

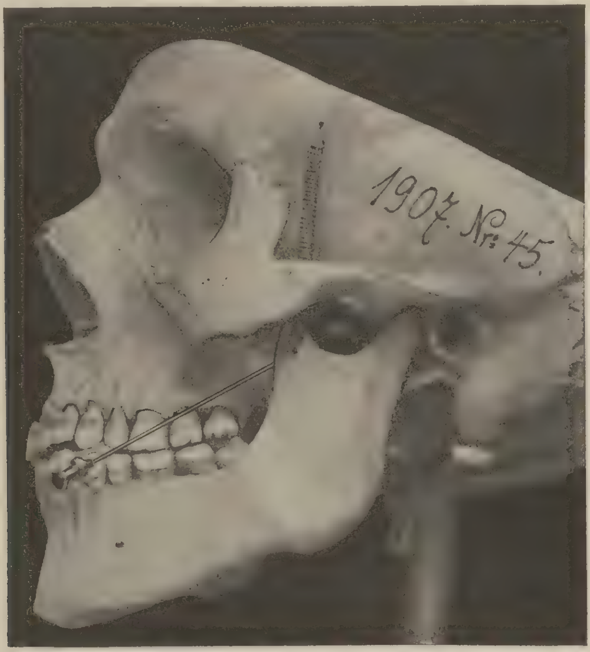


FIG. 74.—Puncture of the Gasserian ganglion. Position of the needle in the skull.

puncture can be changed in case of necessity without causing pain. With the finger in the mouth as a guide, the needle is now passed from the abovementioned point beneath the mucous membrane of the mouth, then upward between the ascending ramus of the jaw and the maxillary tubercle until the point reaches the smooth, hard infratemporal surface just in front of the foramen ovale. The operator feels with the end of the needle, in a posterior direction, bearing in mind the relations to each other of the Gasserian ganglion, the long axis of the orbit, and a line connecting the

[1] Dr. Haertel was kind enough to loan the illustrations shown in Figs. 72 to 74. The writer unfortunately has not been able to describe in detail at this time the results in connection with his work on the puncture of the trigeminus trunk and the Gasserian ganglion.

articular tubercles of the zygomas, a point so well observed by Haertel. If the patient is viewed from the front, the needle should lie in a plane intersecting the pupil of the eye of the same side (Fig. 75). Viewed from the side the needle should lie in a plane intersecting the articular tubercle (Fig. 76).

It is very essential to locate the infratemporal plane so that the needle will not be passed behind the foramen ovale. To guard against this it is best to pass the needle in the plane intersecting the pupil, as shown in Fig. 75, sharply upward so that when viewed from the side the plane of the needle instead of intersecting the articular tubercle intercepts the middle of the zygoma. The hub of the needle is then gradually raised,

FIG. 75.—Puncture of the Gasserian ganglion, viewed from in front.

keeping it always in the plane of the pupil until the point of the needle passes behind the infratemporal plane. These manipulations become clear if they are carried out on the cadaver, with a skull alongside as a guide. Fig. 77 shows a patient with the needle in the ganglion. Radiating sensations in the lower jaw is evidence that the mandibular nerve is located. The distance from the point of entrance to the foramen ovale is 5 to 7 cm. The needle is inserted for 1 to 1.5 cm. farther in the same direction until the patient complains of paresthesia in the upper jaw.

The foramen ovale can be reached objectively, independent of any statement from the patient, and its position readily determined from the manner in which the needle suddenly passes into the depths behind the

infratemporal plane. The Gasserian ganglion can, therefore, be punctured under general anesthesia, which is of the utmost importance in the treatment of very severe trigeminal neuralgia. As soon as the needle is properly placed, 0.5 to 1 cm. of a 2 per cent novocaine-suprarenin solution

Fig. 76.—Puncture of the Gasserian ganglion, viewed from the side.

Fig. 77.—Needle in ganglion preparatory to the injection of alcohol.

is injected. Nerve blocking occurs immediately in all three branches of the trigeminus and lasts from one to three hours. The injection is frequently accompanied by vomiting and attacks of vertigo, particularly if more solution is injected than mentioned above. The technic is not at all difficult after a little practice, unless the configuration of the skull is abnormal. Whether the method of intracranial injection is quite free from danger remains to be seen. In inducing anesthesia of the trigeminal nerves for operative purposes, naturally the simplest and least dangerous method should be employed. It is suitable in the revolutionary treatment of trigeminal neuralgia as introduced by Schloesser, but it is impossible at this time to give full details. Haertel lost one of his patients from meningitis and in a few cases the eye has been damaged as a result of thrombosis or embolism of the central artery of the retina. The method in general should be used for operative anesthesia only when injection of the nerves at the base of the skull or of the lingula does not suffice.

OPERATIONS IN THE ORBIT. EYE OPERATIONS.

Cocaine anesthesia first found practical application in operative ophthalmology (see Chapter VII).

General anesthesia as used in ophthalmology is always attended by certain serious disadvantages which at the present time have happily been overcome by the introduction of local anesthesia.

One of the most important of these disadvantages lies in the fact that general anesthesia of the eye must be very deep to be effective, much deeper than in operations upon other parts of the body, because of the well-known fact that sensation of the eye is the last to disappear. The dangers of narcosis increase with its depth. Furthermore, every interruption due to respiratory difficulties or to vomiting is dangerous in so far that certain operations on the eye cannot be interrupted without jeopardizing the result. Finally in many operations the coöperation of the patient in making active movements of the eye is advantageous. So it happens that local anesthesia has proved to be the most important anesthetic procedure in ophthalmology, and is used in the majority of all eye operations today.

Ophthalmologists use local anesthesia partly as an instillation and partly as subconjunctival and subcutaneous injections. The conjunctival sac is a particularly suitable place for the superficial application of anesthetic agents, because when the eye is closed it forms a closed sac which holds the instilled anesthetic for a considerable time and spreads it over tissues which have a high power of absorption. For this reason it is easy to bring large quantities of an anesthetic substance in contact with the cornea and conjunctiva, much more than in applications to the nose and larynx, as in the latter case the drug is in contact with the mucous membrane for only a short time. For the same reason anesthesia of the eye is not confined to the surface but penetrates the cornea and the fluid contents of the anterior chamber, even at times affecting the bulb to a greater

or less extent. Dilute solutions can be used in the eye very advantageously for local anesthesia. All substitutes for cocaine are tested by preference in the eye. It is a very sensitive organ and, therefore, a particularly advantageous field for testing new substances as to their anesthetic action as well as their irritating properties.

Cocaine has never been displaced from its dominant position in ophthalmology by any of the newer drugs. For its early practical use in eye operations see Chapter VII. Almost all the new substitutes cause more or less irritation upon instillation into the conjunctival sac. β-eucaine, tropacocaine, and holocaine are the only substitutes which have found any advocates among the various substitutes. Holocaine, however, owing to its marked toxic properties, has only been used for very superficial anesthesia. Tropacocaine (3 to 5 per cent) and holocaine (1 per cent) have been highly valued as anesthetic substitutes, owing to the fact that they do not irritate, their action is rapid and profound, and, in contrast to cocaine, cause neither paralysis of the pupil and accommodation nor any change in ocular tension. Recently novocaine and alypin have found considerable support in the profession, the former in combination with akoin (Hirsch). Reichmuth still holds that cocaine is the best anesthetic for the ophthalmologist, inasmuch as it causes the least injury to the eye, and for this reason the majority of ophthalmologists have remained true to it. As the instillation of fairly concentrated cocaine solutions is not likely to cause toxic symptoms, there is no reason why this remedy should be supplanted by any other. For all injections, however, novocaine is to be preferred and cocaine absolutely avoided. Ophthalmologists were likewise the first to recognize the effect of suprarenin upon the action of cocaine (see Chapter VIII).

Anesthesia of the Eye by Instillation.—Instillations of 2 to 5 per cent cocaine solutions are used, and the activity of the drug can be markedly increased by the addition of suprarenin. For superficial operations upon the conjunctiva and cornea a single instillation is, as a rule, sufficient. The results following its use are as follows: The space between the lids increases, giving rise to an apparent protrusion of the bulb, the pupil is enlarged, and the accommodation, depending upon the dosage, is more or less affected. The conjunctiva and cornea become completely anesthetic to touch as well as to the action of heat or cold. The blood supply of the conjunctiva becomes also markedly diminished. Anesthesia following the use of strong solutions which have been repeated frequently is very prompt in normal eyes, and its duration is of variable length. The instillation of a 2 per cent cocaine solution into the eye produces anesthesia in about two minutes and continues from seven to ten minutes, after which time sensation gradually returns. In the older literature much is said regarding the injurious action of cocaine upon the eye. The conjunctival irritation is often due to contamination of the solution by acids or strong antiseptics, particularly sublimate, whereas the affection of the cornea is due in large part to the non-observance of certain precautionary rules regarding the use of cocaine. Owing to the increase

in the space between the lids and the absence of winking, due to the action of cocaine, the cornea may become dry, the degree depending upon the duration of the anesthesia, and thus occasion cloudiness or casting off of the epithelium to a varying extent. It may even cause infection with the formation of ulcers. It is probable that some of these injuries to the cornea are due to the improper use of antiseptic substances. The injurious results of drying can easily be avoided during operation if the operator or an assistant closes the eye frequently or keeps it moist by the application of compresses (Czermak). The mydriatic action of cocaine can likewise be avoided by the addition of miotic drugs to the instilled solution.

Following a single instillation of cocaine into the eye the anesthesia is limited to the surface, whereas, if a 5 per cent solution is instilled every three minutes for half an hour, the iris will, as a rule, become insensitive. The operations that can be performed upon the eye following the instillation of cocaine are superficial operations on the conjunctiva, removal of foreign body from conjunctiva and cornea, cauterization of corneal ulcers, plastic operations on the cornea, cataract operations, and operations upon the lens and iris.

Subconjunctival Injections.—Subconjunctival injections are made, as a rule, after the conjunctiva has been rendered insensitive in the usual manner. The injection method is used in anesthetizing the iris in operations for glaucoma in which the instillation method is not sufficient, and in strabismus operations. As a rule, rather concentrated solutions are used (3 to 5 per cent). These solutions are not free from toxic action, but, nevertheless, poisoning in ophthalmology very seldom takes place. Schwarz recommends a 2 per cent solution of cocaine with the addition of 1 to 5000 to 1 to 10,000 suprarenin in operations that require anesthesia of the entire iris, such as the separation of numerous synechia. The solution must be circularly injected without interruption beneath the conjunctiva around the entire cornea.

The anesthetic action takes place after about five minutes. Haab suggested for similar purposes the placing of cocaine crystals in the anterior chamber of the eye so that direct action could be produced upon the iris. These crystals are obtained by evaporating alcoholic solutions of cocaine. Others have suggested the injection of anesthetic solutions into the anterior chamber. In operations for strabismus the anesthetic solution is injected at the point where the conjunctiva is to be opened for the purpose of reaching the necessary tendon; the solution is spread throughout the tissues by gentle massage applied to the lid, after which anesthesia occurs in about five minutes.

Innervation of the Orbit.—The orbit and globe are innervated by the ophthalmic nerve; its course in the orbit has already been described on page 218, Fig. 58. Besides this nerve the zygomatic branch of the maxillary nerve passes through the orbital cavity and is distributed to the skin of the temporal and zygomatic region, and also to the outer canthus of the eye.

Exenteration of the Orbit.—An injection of 10 cc of a 1 per cent novocaine-suprarenin solution can be made without danger in the deepest

portion of the orbit behind the bulb. Long needles and the median and lateral orbital injections are used (see page 219). These injections in connection with an additional one into the foramen rotundum (see page 221) will induce complete anesthesia of the entire orbital cavity with its contents and also the eyelids. The author has repeatedly performed this operation in connection with resections of the upper jaw; solutions injected in this way block the optic nerve. Anesthesia of the same extent can be produced by injections into the Gasserian ganglion according to Haertel's method.

Enucleation and Exenteration of the Eye-ball.—Schleich has reported enucleation of the eye by injections of his cocaine solution, but has not given definite details as to the technic. Weiss later used the Schleich method in 5 cases; in 3 cases he used Schleich solution No. 3, with 0.01 per cent of cocaine, and in 2 cases 0.2 per cent cocaine. After cocainizing the conjunctiva with a 2 per cent solution he rendered the ocular conjunctiva markedly chemotic by the injection of Schleich's solution, after which he pushed the needle carefully into the axis of the orbit to both the nasal and temporal side of the bulb and infiltrated the deeper parts of the orbital cavity. The operations were not entirely free from pain, particularly in those cases where long-continued inflammation had previously existed. This same observation was made by Meyers. For the certain blocking of the ciliary nerves Schleich's solution is just as unsuitable as it has proved to be in blocking nerves in other parts of the body. Further reports regarding enucleation have been made by Hackenbruch. After the cocainization of the conjunctiva and cornea he injected a 0.5 per cent solution of eucaine and the same percentage of cocaine circularly behind the bulb, after which a glaucomatous eye became painless and could be readily enucleated. Haab used the same cocaine and eucaine solution but limited its application to those cases in which inflammation was absent; he was thus able to operate without pain. He injected the solutions first above the attachments of the eye muscles and after separating them injected large quantities behind the globe with curved needles. In about five minutes anesthesia occurred. If the capsule of Ténon remains intact, the entire bulb can be made insensitive by filling this space with an anesthetic solution, but in diseased conditions of the eye adhesions frequently take place between the bulb and this fascia, for which reason results are often imperfect. In recent years, since the introduction of suprarenin, ophthalmologists have been using injection anesthesia more and more frequently for enucleations and exenterations of the orbit. The method consists in infiltration of the orbit following a cocainization of the conjunctival sac.

Loewenstein passes a straight needle through the lateral commissure of the lid slightly below its center. The needle is then directed more toward the median line until its point reaches a depth of 4.5 cc, which brings it in the neighborhood of the optic nerve and ciliary ganglion. In this position 1 cm. of a 1 per cent cocaine solution with the addition of suprarenin is injected. The bulb is also circularly injected beneath the

conjunctiva with 0.5 cc of the same solution. In 24 out of 25 cases the bulb was made anesthetic.

Mende reports the results obtained by Siegrist with reference to his previous work. He recommends the use of a slightly curved needle which is introduced from the temporal and nasal side back of the bulb to the points of entrance of the optic and ciliary nerves, injecting at each point 2 cc of a 0.5 per cent novocaine solution with the addition of suprarenin. Subconjunctival injections of 1 cc of the same solution are made in the region of the attachments of the recti muscles. From 1906 to 1910, 155 exenterations and enucleations were performed under local anesthesia and 61 under general anesthesia. The patients were given sedatives and narcotics before the operation. In the 155 cases anesthesia was insufficient in 8 cases owing to improper technic and lack of observance of the proper indications. Local anesthesia is contraindicated in excitable patients, in severe injuries of the globe, and purulent conjunctivitis and perforating panophthalmitis, whereas irritation of the eye has no effect on the results of this method.

Seidel, who was not always satisfied with the method of Siegrist, injected 1 to 2 cc of a novocaine-suprarenin solution beneath the conjunctiva around the bulb. He then injected the connective tissues behind the bulb from 4 points with a straight needle passed through the conjunctiva to the middle of a line connecting the optic foramen and the point of entrance of the optic nerve into the bulb. During the insertion of the needle 1 cc of this solution was injected retrobulbar. The operation was begun twenty minutes after the injection. If the conjunctiva is infected Seidel makes the injection through the skin at the orbital border, or he introduces the needle at a point below the zygoma, passing it through the orbital fissure into the posterior part of the orbit, depositing 4 to 6 cc of a 4 per cent novocaine-suprarenin solution. The author has had no personal experience with operations carried out in this way, but believes it would be more convenient to inject back of the bulb from the orbital border than through the conjunctiva, as has already been described in operations for exenteration of the orbit. Seidel has recently come to the same conclusion.

Krönlein's Operation.—Haertel has injected the Gasserian ganglion for this operation. He describes his method of inducing anesthesia for this operation as follows; The line of the skin incision is made anesthetic by infiltration. The needle is introduced into the orbital cavity at the upper and outer orbital angle and 5 cc of a 4 per cent novocaine-suprarenin solution injected along the outer wall. In the same manner 6 cc of 1 per cent solution are injected on the posterior surface of the processes fronto-sphenoidalis, and finally 3 cc of a 2 per cent solution are injected along the inferior orbital fissure from the outer and inferior angle of the orbit.

Operations upon the Eyelids and Tear-sac.—Operations confined to the eyelids require neither central orbital injections nor blocking of the second branch of the trigeminus. To render the upper lid insensitive a point of injection is marked in the center of the upper orbital ridge and

3 to 5 cc of a 1 per cent novocaine-suprarenin solution injected along the bony orbital edge (Fig. 78). The anesthesia will also include the conjunctiva; the same procedure can be carried out on the lower lid. In the latter, injections into the infraorbital foramen can also be used (see page 220). The entire cheek is thus made insensitive at the same time. It should also be remembered that the median end of the lower lid is innervated by the infratrochlear nerve. The latter can be reached by

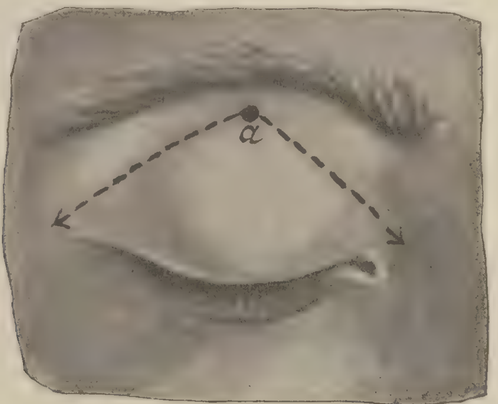


Fig. 78.—Anesthesia of the upper eyelid.

passing the needle above the median to the inner canthus and injecting 2 cc of a 2 per cent novocaine-suprarenin solution toward the median orbital wall. For operations on the tear-sac Seidel, as a result of extensive experiments, recommends blocking the anterior ethmoidal nerve by the medial orbital injection (page 219). In order to be certain of reaching the nerve he makes a second injection on the medial orbital wall, introducing the needle at the inner end of the lower eyelid.

OPERATIONS UPON THE SOFT PARTS OF THE FACE.

Local anesthesia is of great value in all operations on the face. General narcosis is always troublesome. Lexer calls attention to the special advantage of local anesthesia in plastic operations, which can be done with the patient sitting, thus making it possible to observe better the symmetrical relations of the face.

The extent of the innervation of the face from the three branches of the trigeminus and their overlapping fibers, which is very variable, will be seen in Fig. 79. The blocking of the third branch of the trigeminus at the foramen ovale produces complete anesthesia of only a small area of variable size on the lower lip on account of an overlapping of the cervical nerves. The blocking of the second branch of the trigeminus produces an anesthetic area of the face not much larger than that following injections into the infraorbital foramen (see page 220).

The skin of the nose is innervated by the second branch of the trigeminus and to a greater or lesser extent by the end branches of the ethmoidal nerves derived from the first branch of the trigeminus. This applies particularly to the tip and alæ of the nose (see Fig. 40, page 202). The central blocking of the trigeminal branches is of much importance in anesthesia of the cavities of the face, but the soft parts, owing to the overlapping of the neighboring nerves, and those from the opposite side, must be circuminjected to produce anesthesia. The typical form of these circuminjections has already been described in connection with operations upon the jaw. The anemia obtained from this injection is of the greatest

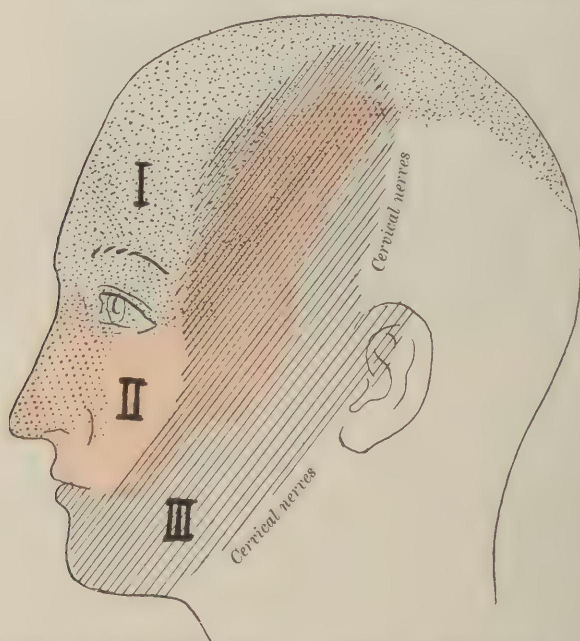


FIG. 79.—Innervation of the face and scalp. (Corning.) Black dotting, R. I. N. Trigemini; red shading, R. II. N. Trigemini; black shading, R. III. N. Trigemini.

importance. Only the blocking of all three branches of the trigeminus by injection into the ganglion will cause extensive anesthesia of the face. Even the areas near the midline must be injected unless the Gasserian ganglion is blocked on both sides. Haertel has done this in one case. In superficial operations upon the soft parts of the face, central injections at the base of the skull are, as a rule, not necessary; circuminjection of the part is usually sufficient.

Anesthesia of the Exterior of the Nose, Upper Lip, and Cheek.—As an example of operations upon the nose we will describe the removal of a rhinophyma (Fig. 80). As a rule, three points of entrance for the needle are necessary, one on either side of the alæ of the nose, the third upon the

bridge at the bony and cartilaginous junction. From the two former points 0.5 per cent novocaine-suprarenin solution is freely injected subcutaneously along the border of the pyriform aperture as far as the bridge of the nose. This injection must sometimes be supplemented by injections from wheals on the bridge of the nose. Injection is then made beneath the attachment of the alæ and frenulum to the upper lip, and require 20 to 25 cm. of the solution. Following this injection the tip and alæ of the nose, including cartilage, mucous membrane and frenulum, will be rendered insensitive. This operation for rhinophyma and the excisions of areas of lupus will be found of definite advantage owing to the anemia of the operative field. In case the upper lip is to be included in the anesthetic field, injections of 10 cc of a 0.5 per cent novocaine-suprarenin solution are made from points 1 and 2 in two lines subcutaneously and submucously to the angle of the mouth, the needle being guided by the finger in the mouth (Fig. 81).

Fig. 80.—Circuminjection of the nose for rhinophyma.

A still larger anesthetic field will be noted in Fig. 82. Besides circuminjecting from points 1–5–3–6–2, it is necessary to inject a line to either side from point 4, likewise on either side an injection into the infraorbital foramina from points 5 and 6. The lines of injection, 1–5, 2–6, are made from points 5 and 6, exclude the ethmoidal nerves, as well as an injection into the infraorbital foramen guiding the needle by the finger under the lip, as shown in Figs. 81 and 82.

Hare-lip operations are regularly performed without general anesthesia. The upper lip is injected on both sides in a line from the angle of the mouth to the alæ of the nose, using 2.5 cc of a 0.5 per cent novocaine-suprarenin solution on either side. The anterior surface of the upper

jaw is also injected as far as the infraorbital foramen. Injections are then made beneath the alæ of the nose, in single hare-lip on one side, and in double hare-lip on both sides, using 5 cc of the same solution. The injections control the hemorrhage; children, as a rule, sleep during the entire operation. Splitting the cheek, as a preliminary to operations in

Fig. 81.—Anesthesia of the outer parts of the nose and upper lip.

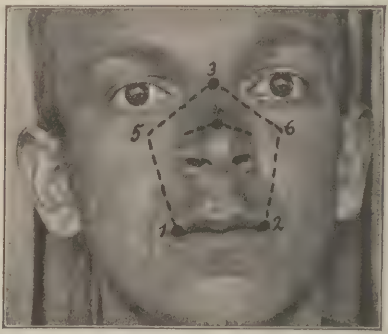


Fig. 82.—Anesthesia of the outer parts of the nose, upper lip, and cheek.

the mouth, is accomplished by simple infiltration of the proposed line of incision. For this a single point of injection at the anterior border of the masseter muscle is sufficient (Fig. 83). With the index finger in the

Fig. 83.—Injection for transverse cutting of the cheek.

mouth as a guide the proposed line of incision is injected with long needles under the skin and mucous membrane as far as the angle of the mouth.

Operations upon the Lower Lip and Region of the Chin.—For operations limited to the lower lip, a wedge-shaped circuminjection is made according to the method of Hackenbruch (Fig. 85, 1–4–5). From point 1 marked

on the chin the needle, guided by the finger in the mouth, is introduced beneath the mucous membrane to point 4, infiltrating the entire line; the needle is then partly withdrawn and a subcutaneous infiltration is made to point 4. A similar injection is made toward point 5. For this injection, as is shown in Fig. 85, 20 to 25 cc of a 0.5 per cent novocaine-suprarenin solution are necessary; the entire area as indicated by lines 1–4 5 is rendered insensitive. In cases of carcinoma the line of injection must be removed some distance from the lesion, points 4 to 5, as a rule, being at the angle of the mouth. The wedge-shaped excision in carcinoma should not correspond to the lines of injection 1–4–5, but should lie within these lines. It is possible in this way to avoid the infiltration of diseased tissues. In case it is desired to anesthetize the larger part or the

Fig. 84.—Technic for injection of the lower lip.

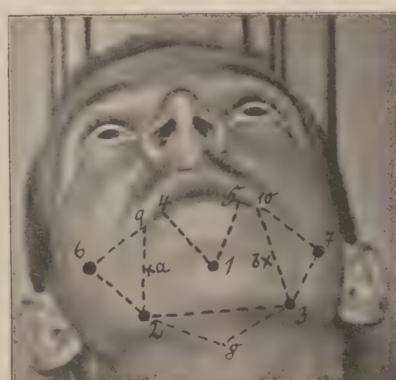


Fig. 85.—Circuminjection of the lower lip and chin. *a*, *b*, points of emergence of the mental nerve.

entire lower lip with the adjacent skin of the chin, 2 points for injection are made at 2 to 3 (Fig. 85) and the tissues infiltrated in the lines designated by 9–2–3–10. Where the soft parts join the bone, injection is first made deep to the periosteum, then under the skin. The remaining portion of the injection is performed, as already described, guided by a finger in the mouth and using 0.5 per cent novocaine-suprarenin solution. Complete anesthesia is not obtained by this injection; to do this it is necessary to anesthetize the inferior mental nerves at their exit from the foramina *a* and *b*, or to block the inferior alveolar nerve at the lingula. After this the entire field of operation and the underlying bone should be rendered insensitive. Fig. 85 shows how the anesthetic field of the cheek and submental region can be enlarged; this is done by marking additional points for injection at 6 and 7. By circuminjection the field

designated by 9–7–2–8–3–7–10 or portions of it can then be rendered anesthetic. The injection from 2 to 6 is carried out as was described for lower lip anesthesia and from 6 to 9 like that for transverse cheek incisions. Where plastic operations are to be performed on the face with pediculated flaps, the method as described above should be used, except that the anesthetic should be injected some little distance from the pedicle, for self-evident reasons. The form of anesthesia must therefore be guided accordingly.

OPERATIONS ON THE NASAL CAVITIES AND THE BONY PART OF THE NOSE.

The nasal cavities in their anterior portions are innervated by the ethmoidal and ophthalmic nerves, the posterior portion by the maxillary nerve. Figs. 86 and 87 show the nerve distribution schematically. The sphenoid cavity and the antrum of Highmore are supplied by the maxillary nerve alone. The frontal sinuses are supplied by the ethmoidal nerves. The cells of the ethmoid are supplied by both of these nerves.

Fig. 86.—Innervation of the nasal septum. *I*, olfactory nerve; *II*, ethmoidal nerve; *III*, maxillary nerve.

Cocainization of the nasal mucous membrane has been of marked importance in the development of rhinology. The exact examination of the nasal cavities and accessory sinuses as well as the performance of many operations have been greatly facilitated and often made possible only by cocainization of the nose. This agent not only renders the mucous membrane insensitive with an inhibition of its reflexes but also enlarges the nasal cavities through its power to contract the bloodvessels of the

mucous membrane, making them much more accessible. This same condition can at present be produced with many other anesthetic substances by the addition of suprarenin, but cocaine has never been displaced in rhinology by the newer substitutes. Among the newer preparations alypin has been highly praised by both Seifert and Ruprecht. They use this agent in a 10 per cent solution, Ruprecht adding suprarenin.

Cocaine solutions are used in the following manner (these directions are given by Bresgens): "A bit of cotton is fastened to a very fine sound and saturated with the anesthetic solution. After illuminating the nasal cavities the cocaine solution is gently rubbed over the nasal mucous membrane, beginning in the anterior portion and proceeding backward, also touching the middle and lower nasal tracts. The patient is then directed

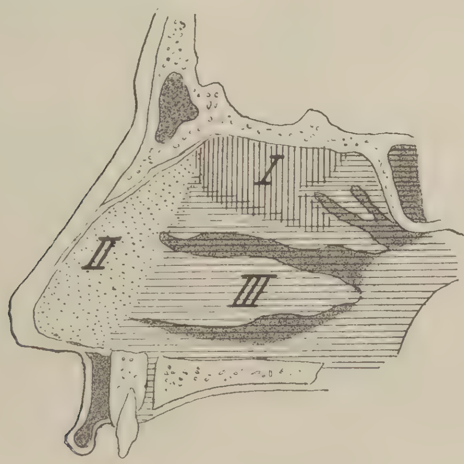


FIG. 87.—Innervation of the lateral wall of the nasal cavity. *I*, olfactory nerve; *II*, ethmoidal nerve; *III*, maxillary nerve.

to bend his head sharply forward so that the anesthetic dose not run into the throat; he is also at the same time directed to blow the side of the nose which has been anesthetized, the opposite half of the nose being closed. The middle portion of the nasal cavity is anesthetized, the anesthesia being continued high up in the nose, after which the lower portions are again touched with the cocaine solution. This entire procedure is repeated once more, after which in most cases the entire nasal mucosa becomes anesthetic and shrunken. After one to two minutes the patient again blows that side of the nose. In the majority of cases the second application of the anesthetic is sufficient—in some cases one application, whereas in other cases four or more applications must be used."

In cases where it is only necessary to sound the frontal or maxillary sinuses, it is sufficient to anesthetize only the mid-nasal tracts, and to

place a small cotton tampon saturated with the solution at the outlet of the cavity to be sounded.

Anesthesia produced in this way is limited to the mucous membrane. Whenever it becomes necessary to anesthetize the bony or cartilaginous part of the nose the submucous membranes must be infiltrated with a 2 per cent novocaine-suprarenin solution. This is readily carried out upon the septum and makes the operation for deviations of this structure very easy. The injection is made with a 1 cc syringe and very fine needle. Beginning anteriorly the injection is extended backward on both sides of the septum as far as the limit of the field of operation. The desired operation can then be very easily performed, owing to the anemia from the suprarenin. Killian advises that injections be made at the points

FIG. 88.—Carcinoma of the skin and bony parts of the nose.

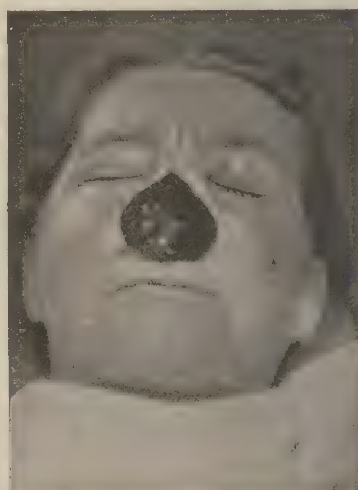


FIG. 89.—After operation, patient is unable to open eyes owing to edema of the upper lids.

of emergence of the ethmoidal and nasopalatine nerves (see page 220). In regard to the details of anesthesia for the numerous superficial operations in this particular field the reader is referred to works on rhinology.

For extensive operations on the bony structure of the nose neither anesthesia of the mucous membrane nor submucous injections from inside the nose, nor the circuminjection as described on page 243 will be sufficient. In such cases the method as described by Peuckert and Offerhaus must be used. An example will probably best explain the technic. Take, for instance, excision of a carcinoma of the nose in which not only the entire nose was removed but also the nasal bones, the edges of the pyriform aperture, the anterior part of the hard palate, and the exenteration of the entire interior of the nose (see Fig. 89). The injection begins with blocking of both maxillary nerves from the lower border of the zygoma (see

page 221) and blocking of the ethmoidal nerves by a bilateral median orbital injection (page 219). The injection of the outer nose with a 0.5 per cent novocaine-suprarenin solution is carried out according to Fig. 90, in which the points for injection are the same as those used for blocking the maxillary nerve. A third point for injection lies on the bridge of the nose. The operation is painless and bloodless. Fig. 89 shows the patient just after completion of the operation. The eyelids are edematous, for which reason the patient is not able to open the eyes.

With this same procedure the author has repeatedly performed the preliminary operation to freely expose the interior of the nose and the base of the skull; for the reflexion of the outer nose according to Kocher; and for the temporary reflexion of both bones of the upper jaw, also according to Kocher for the removal of tumors. It is advisable when operating

Fig. 90.—Figure for circuminjection in nasal operations. 1, point for the median orbital injection; 2, point for the injection of the maxillary nerve.

upon tumors at the base of the skull and the pharynx to again inject the visible portions of the pharyngeal wall after exposing the operative field, and to infiltrate the nasopharyngeal fibroma at its attachment before completing the extirpation.

Anyone who has seen this operation carried out under local anesthesia, and has learned the method of blocking the trigeminus trunk, would never again think of performing it under general anesthesia or without the anemia induced by suprarenin. For operation upon the hypophysis carried out through the nose no more suitable means of anesthesia could be found than the one just described.[1]

[1] v. Eiselsberg: Arch. f. klin. Chir., vol. **100**, p. 70. v. Eiselsberg in the past has also performed operations upon the hypophysis by means of the external circuminjection of a 0.5 per cent novocaine-suprarenin solution for the purpose of checking hemorrhage.

OPERATIONS UPON THE FRONTAL SINUSES.

The operations upon the frontal sinuses which previously were performed under local anesthesia were confined to the simple opening of these cavities with a chisel after infiltration of the soft parts overlying the small operative field. This anesthesia has, as a rule, proved insufficient. Peuckert was the first to develop our present technic of anesthesia for the radical operation, consisting in complete removal of the anterior and posterior wall known as Killian's operation. This technic was partially described in the second (German) edition of this work; 13 cases were reported later in which the radical operation was performed, some being unilateral, others bilateral.

Fig. 91.—Figure for circuminjection in operations upon the frontal sinuses. 1, point for the medial orbital injection; 2, point for the injection of the maxillary nerve.

Fig. 92.—Figure for circuminjection in bilateral radical operations upon the frontal sinuses.

It is usually sufficient to anesthetize with the median orbital injection (see page 219), introducing the anesthetic solution in the roof of the orbit; the lateral injection can then be omitted. Previously the attempt was made to block the second branch of the trigeminus which innervates the nasal mucous membrane by applying solutions of cocaine or alypin to the mucous membrane before beginning the operation. Inasmuch as patients complained of pain when connecting the frontal sinuses with the nose and on opening the posterior cells of the ethmoid, it is now customary to block the maxillary nerve by preference at the foramen rotundum (page 221). The operative field is circuminjected in the unilateral operation from seven points of entrance, the positions of which are indicated in Fig. 91. One of these corresponds to the point necessary for the median orbital injection. The operative field on the forehead and nose is circum-

FIG. 93.—Radical operation for empyema of the frontal sinuses. (Killian's operation.)

FIG. 94.—Radical operation for empyema of the frontal sinuses. Complete removal of the lateral and posterior wall.

injected from points on the orbital border, as shown in the diagram. Injections are then made beneath this edge and under the roof of the orbit. For the blocking of the ethmoid and maxillary nerve 10 cc of a 2 per cent novocaine-suprarenin solution is necessary. For the circum-injection 40 to 50 cc of a 0.5 per cent novocaine-suprarenin solution are used. The technic for injection in bilateral operations is shown in Fig. 92. The field of operation after these injections is absolutely painless. The ethmoidal cells can be removed as far as necessary, also the anterior and upper wall of the frontal sinuses. The orbit is accessible even to the deepest parts so that the opening can be made through the nasal bone and mucous membrane into the nasal cavities. The anemia of the operative field simplifies this procedure very much. Nobody will be induced to perform this operation under general anesthesia after observing the accessibility and learning the advantages of the method just described. Figs. 93 and 94 represent photographs taken of two patients during and at the completion of the operation.

OPERATIONS UPON THE JAWS.

The Operative Treatment of Empyema of the Antrum of Highmore.—There are really only two operations for treating suppurations in the upper jaw: (1) The opening of the antrum of Highmore from the canine fossa in acute cases, and (2) the removal of the anterior and nasal wall, including a portion of the pyriform aperture in chronic suppurative processes, according to Friedrich. The operation on the bone in the latter case can be carried out by incision of the outer soft parts or from within the mouth, if it can be opened sufficiently wide and the upper lip is fairly movable. The use of local anesthesia simplifies this radical operation so that the patient can be discharged with a healed wound after one to two weeks.

The upper jaw is entirely innervated by the maxillary nerve. In the radical operation the ethmoidal nerve is also encountered. Both of these trunks must be blocked. Anesthesia of the maxillary nerve in operations for empyema of the upper jaw was suggested by Muench in 1909. This anesthesia is, however, not sufficient, the technic of injection being of secondary importance to the pronounced suprarenin anemia.

Anesthesia for the radical operation is performed in the following manner: Three points of entrance are marked as shown in Fig. 95, the first and second points corresponding to the point of injection for blocking the maxillary and ethmoidal nerves. The third adjoins the ala of the nose. From point 1, 5 cc of a 2 per cent novocaine-suprarenin solution are injected into the pterygopalatine fossa, and upon the withdrawal of the needle 5 cc of a 0.5 per cent novocaine-suprarenin solution are injected to the maxillary tubercle. From point 2 the median orbital injection is made with 2.5 cc of a 2 per cent novocaine-suprarenin solution (see page 223), after which the soft parts are infiltrated, guided by a finger in the mouth, in a line from point 1 to the angle of the mouth, just as was done

in the transverse splitting of the cheek (page 244). From 15 to 20 cc of a 0.5 per cent novocaine-suprarenin solution are used. This injection excludes the lateral innervation from the third branch of the trigeminus, at the same time causing contraction of the end branches of the external maxillary artery. From point 3, 10 to 15 cc of a 0.5 per cent novocaine-suprarenin solution are injected along the pyriform aperture under the alæ of the nose and frenulum and in the midline of the upper lip as far as the red margin. The latter can be more readily performed without another point for injection if the lip is raised and drawn toward the opposite side. The injection in the upper lip controls the overlapping nerves and arteries from the opposite side. The radical operation can now be carried out without pain or loss of blood, either from without, according to the method

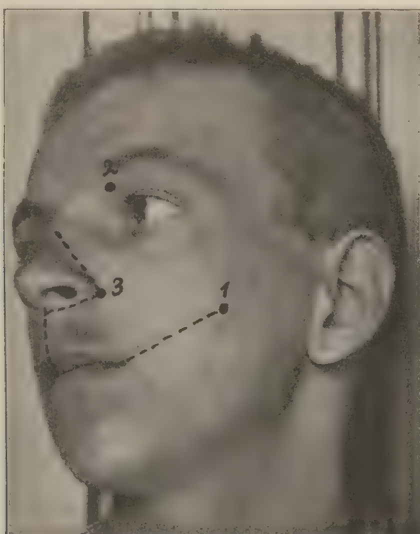


FIG. 95.—Circuminjection for the radical operation for empyema of the antrum of Highmore. 1, point of injection for the maxillary nerve; 2, point for median orbital injection.

of Friedrich, or from within the mouth after cutting the mucous membrane from the middle line to the attachment of the zygomatic process to the maxilla.

For the simple opening of the antrum of Highmore from the canine fossa the same form of injection is used as for the extraction of several teeth from the upper jaw on one side (page 263), except that the gums may be disregarded. The injection of the anterior surface of the upper jaw eliminates the innervation from the infraorbital nerves which pass into the antrum of Highmore and at the same time renders the operative field bloodless. The other injection at the tubercle of the maxillary bone blocks the superior, posterior, and median alveolar nerves (Fig. 102).

Both of these injections can be readily made from a single point of

entrance situated beneath the lower angle of the zygoma (Fig. 96). A wheal is made at this point and the needle inserted below the infraorbital foramen and pushed as far as the bone of the nose. At this point 5 cc of a 2 per cent novocaine-suprarenin solution are injected. The needle is now partially withdrawn and passed toward the posterior surface of the upper jaw, injecting at this point 5 cc of a 2 per cent or 10 cc of a 1 per cent novocaine-suprarenin solution. The introduction of the needle to the foramen rotundum is not necessary. The injection, as is frequently done by dentists, can be carried out from within the mouth (see page 263). The customary injection of the anterior surface of the upper jaw is not sufficient for complete anesthesia of an acutely inflamed sensitive mucosa of the antrum of Highmore, as can be readily understood from the innervation of the upper jaw.

FIG. 96.—Direction of the needle in opening the antrum from the canine fossa.

The Resection of the Upper Jaw.—A resection of both halves of the upper jaw, including the hard palate, was performed by Matas in 1900 under local anesthesia. He proceeded as follows: A long needle was passed through the sphenomaxillary fissure to the sphenopalatine fossa of both sides and injection of 3 cc of a 0.2 per cent cocaine solution with 1.5 cc of a 1 per cent cocaine solution made in order to block the infraorbital nerves. In about five minutes the skin of the cheek, upper lip and the alæ of the nose became anesthetic. The septum and hard palate were infiltrated direct with Schleich's solution. The operation was carried out, the only painful part being the cutting of the vomer. This operation was not again attempted; in fact, before the introduction of

suprarenin it was not possible to perform an operation of this kind and duration and be certain of the anesthesia. Total and partial resections of the upper jaw are today performed under local anesthesia as the anesthetic of choice. Peuckert in 1911 was the first to report the technic of the injection, and the author performed resections of the upper jaw eight times under this method of anesthesia. Offerhaus, from his studies of the technic of alcohol injections in trigeminal neuralgia, also used local anesthesia for resection of the upper jaw.

For the unilateral total resection of the upper jaw, if the incision is not to extend beyond the middle line, the unilateral orbital injection (page 219) with the blocking of the maxillary nerve (page 221) is sufficient. If the orbital floor is to be preserved the lateral orbital injection is not necessary. The external field of operation is circuminjected, as is shown in Fig. 97,

FIG. 97.—Circuminjection for unilateral resection of the upper jaw. 1, 1*a*, points for median and lateral orbital injections; 2, point for injecting maxillary nerve.

for the purpose of checking hemorrhage as well as to exclude the innervation from the third branch of the trigeminus and other skin nerves from the opposite side. Four points of injection are necessary. The upper lip can readily be injected from the point adjoining the alæ of the nose (see page 253). The hard and soft palate must also be infiltrated where they are to be cut. For the central injection 10 cc of a 2 per cent novocaine-suprarenin solution are necessary and 80 to 100 cc of a 0.5 per cent novocaine-suprarenin solution for the circuminjection. Haertel also advises painting the palate and pharynx with a 10 per cent cocaine solution to prevent reflex vomiting. A better substitute for this solution would be a 10 per cent alypin-suprarenin solution. In case the orbit is to be cleaned out, 10 to 15 cc of a 0.5 or 1 per cent novocaine-suprarenin solution are injected without fear into the posterior portion of the orbit.

The latter injection can be made in case it becomes necessary to remove the eye during the operation, the patient's consent of course being obtained. This latter operation is photographically shown in Fig. 98. Fig. 99 shows a case in which the floor of the orbit was not removed.

In 2 cases of resection of the upper jaw, described by Offerhaus, it was necessary to block the third branch of the trigeminus owing to the extent of the tumor. On account of the invasion of the sphenopalatine fossa by the tumor, Offerhays failed in 2 cases to interrupt the maxillary nerve in the foramen rotundum. The author had a similar experience in 1 case. In this case he was able to complete the operation by the use of 5 cc of chloroform. In similar cases today we would advise the injection of the Gasserian ganglion according to Haertel's method. The external circuminjection is also necessary.

FIG. 98.—Resection of the upper jaw with removal of contents of orbit under local anesthesia.

The author has repeatedly performed the temporary resection of the upper jaw (under local anesthesia) according to the method of Kocher for the removal of tumors of the nasopharynx. The anesthesia was similar to that described for operations upon the nose and shown in Fig. 88. It was also necessary to infiltrate the hard and soft palate in the line of division. The operation under local anesthesia is surprisingly easy, owing to the absence of the usual severe hemorrhage.

Local anesthesia has completely changed the operation for resection of the upper jaw. It cannot be considered a serious operation today, having lost its terrors, and the difficulties and dangers have been materially lessened. A preliminary operation is not necessary, such as tracheotomy, ligation of the carotids or the intubation of Kuhn, as there is scarcely any

hemorrhage. The operation can now be completed with certainty and without haste and loss of blood. The patients are as well after the operation as they were before; they are never collapsed. It is rarely necessary for them to take to their bed. In 10 resections of the upper jaw we have not lost 1 and have never had a postoperative lung complication. Haertel reports 9 cases from Bier's clinic carried out under local anesthesia and states that the introduction of local anesthesia in major operations upon the areas supplied by the trigeminus is an advancement of vital importance.

Fig. 99.—Resection of the upper jaw for carcinoma of the hard palate with retention of the floor of the orbit. The removed portion is shown above.

Operation upon the Lower Jaw.—The lower jaw and floor of the mouth are innervated by the mandibular nerve. This nerve must be blocked in all operations upon the lower jaw either at the lingula or, if the field of operation extends to the base of the skull, at the foramen ovale. In all operations made from without, the cervical nerves must be blocked by subfascial or subcutaneous circuminjections of the field of operation. As

an example of the simplest case we might take a suture of a fracture or other minor operation on the horizontal ramus of the jaw. The operation is begun by injecting at the lingula (page 226). The field of operation is circuminjected from 3 points with a 0.5 per cent novocaine-suprarenin solution as shown in Fig. 100. The bone can then be exposed in the

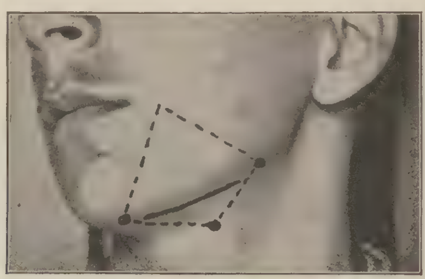


Fig. 100.—Circuminjection for minor operations upon the lower jaw.

injected area and cut, chiseled or sutured. Fig. 101 shows the plan for circuminjection in resection of the left horizontal ramus of the lower jaw for carcinoma of the alveolar process. The submaxillary salivary glands and lymph glands were removed at the same time with the bone. The mandibular nerve was blocked on both sides at the lingula. In case the jaw is to be disarticulated, it will be necessary to block the mandibular nerve at the foramen ovale (page 230) and the lateral lines of circum-

Fig. 101.—Circuminjection for resection of the left ramus of the lower jaw with removal of the submaxillary salivary gland and lymph glands.

injection of Fig. 101 will also have to be extended somewhat farther back. In all cases it is advisable for purposes of producing anemia to infiltrate the entire floor of the mouth with a 0.5 per cent novocaine-suprarenin solution from one of the points beneath the border of the jaw. This should be done even though the entire area has been previously

rendered anesthetic by a central injection. The technic for injections in operations upon the neck must frequently be combined with injections of the lower jaw in cases in which the lymphatics are to be removed. The temporary cutting of the lower jaw will be described in connection with operations upon the tongue and floor of the mouth.

EXTRACTION OF TEETH AND OTHER OPERATIONS UPON THE ALVEOLAR PROCESSES OF THE UPPER AND LOWER JAWS.

History.—Ether and ethyl chloride sprays, which were formerly very much in use for the extraction of teeth, give very unsatisfactory results. Even when ethyl chloride spray is successful for the painless extraction of teeth, it should be borne in mind that the inhalation of small quantities of the drug could have produced sufficient general anesthesia to render the entire body insensitive for a short time (Kulenkampff). This ethyl chloride drunk is possibly satisfactory for the extraction of a single tooth, but its action is not local and the anesthesia could be better carried out by the inhalation of ethyl chloride rather than its application to the gums.

The introduction of cocaine opened up new paths for practical local anesthesia in dentistry. This preparation was injected beneath gums in the neighborhood of the tooth to be extracted. Attempts were also made to anesthetize the inferior alveolar nerves by means of perineural injection. The painless extraction of a tooth by means of subgingival injection is brought about by the diffusion of this drug through the bone or pulp cavity and the nerve supplying the peridental membrane. That dissolved substances can actually diffuse through bone was demonstrated upon a cadaver by Dzierzawskis, who showed that colored solutions injected beneath the gums diffuse to a greater or lesser extent into the bone, in the upper jaw reaching as far as the floor of the antrum of Highmore. It is very improbable (see page 151) that solutions injected beneath the mucosa or periosteum can be mechanically forced into the bone. By means of such an injection the fluid under great pressure will naturally take the course of least resistance which would be in the soft parts surrounding the bone. We have, therefore, come to believe that this process is carried on by diffusion. The extent of the anesthetic or colored solution so injected must depend upon the concentration of the quantity injected into the gums. This must be true, inasmuch as the diffused substance becomes more and more dilute the farther it is removed from the point of injection, and therefore the solutions which reach the pulp and innervate the roots must be of sufficient concentration to be effective. The agent requires considerable time to reach the points above mentioned and a tooth can never be extracted immediately without pain, no matter how much has been previously injected into the gums.

Owing to the danger, injections of 5 to 20 per cent of cocaine solutions into the gums were soon given up by dentists and replaced by solutions of 1 to 2 per cent. The injection of a 1 per cent cocaine solution into the gums has been proved without danger in a large number of cases.

Bleichsteiner, in 1892, reported 1400 extractions. Following the use of dilute solutions the anesthesia of the alveolar process became insufficient. It was possible to anesthetize the gums and alveolar periosteum with certainty, but the pulp and peridental membrane could rarely be sufficiently anesthetized for dental operations. The author does not believe that Legrand, a pupil of Reclus, should be credited with the statement that all extractions can be rendered painless with the use of a 1 per cent solution of cocaine, nor does he believe those who are sceptical regarding the use of any injection. Laewen and Quéré made the following statements regarding cocaine injected into the gums and as to its anesthetic effect upon teeth with living pulp: (1) In no case is absolute anesthesia obtained; (2) in the majority of cases there is a marked lessening of pain; (3) in a certain number of cases cocaine does not seem to produce a perceptible analgesia. Quéré, Reclus, and Dastre agree that in the latter class of cases osteoperiostitis of the alveolar process is present. Those with the formation of abscesses and inflammatory infections of the gums are the cases, however, in which anesthesia is most necessary. The conditions are different for the physician because he sees patients whose teeth have been neglected and frequently extracts teeth which the dentist could have preserved. For ten years the author has extracted teeth with a 1 per cent cocaine solution and he agrees entirely with Quéré. This applies not only to cases as above mentioned but also to persons with thick bones in whom the anesthesia frequently failed in extraction of the lower molars. The patient could never be promised a painless extraction, for which reason this method of injection has never been generally accepted. According to the author's experience the anesthesia is more certain if a more dilute solution is used and the gums and alveolar periosteum infiltrated with Schleich's solution. One thing is certain, that these solutions do not produce serious general symptoms when used for these injections. The infiltration of the gums and periosteum with Schleich's solution only produces a satisfactory anesthesia when the tooth to be extracted has been freed of its pulp.

The local anesthetic methods have not been materially improved by the countless combinations of various anesthetic substances. With a 2 or 3 per cent β-eucaine (Reclus, Thiesing) and tropacocaine solutions (Dillenz and others) approximately the same effect is obtained as from a 1 per cent cocaine solution. More highly concentrated solutions of these agents are not free from possible injury and their use may be associated with considerable danger. A description of the various substitutes for cocaine has already been described in Chapter VII. Reports of injury to the gums following the injection of anesthetic solutions occupy a most important place in dental literature. All of the pain-relieving drugs have been attended with swelling and edema of the tissues following injection, but it is difficult to determine whether the swelling should be attributed to the injection or the extraction. The most carefully performed extraction is always followed by more or less crushing of the bone or soft parts and naturally takes place in an operative field which is always infected with

bacteria. If substances which produce tissue injuries are not used, as for instance guaiacol, and if the solutions are sterile and contain the proper quantity of salt, the swelling and edema should not be attributed to the injection but rather to the extraction (Laewen). A pronounced improvement was obtained in anesthetizing the alveolar processes when Wiener, and later Schleich, advised infiltrating the periosteum first with cocaine solution, followed by cooling the cocainized tissues with the ethyl chloride spray.

The advantage of this method depends upon the fact that more dilute solutions of cocaine can be used when the tissues are chilled. When this method of injection is used it is necessary to wait at least five minutes after the gums have been frozen, so that the cocaine can become most effective. The ethyl chloride spray should again be used just before extracting so as to take advantage of the anesthesia due to cold. With this latter method a number of extractions can be carried out without pain which would be only partially anesthetic with cocaine injections. A 0.2 per cent cocaine or 0.5 per cent tropacocaine solution can be employed. It is not advisable to use solutions in the extraction of teeth which are too weak, as the success of the method may be sacrificed by too much dilution.

Cocaine cataphoresis has found many supporters among the American dentists. Whether it is possible to convey the cocaine by means of the galvanic current as far as the alveolus is questionable. A description of this method as well as the complicated apparatus necessary for its use is described in the work by Dorn. For the special history and literature of local anesthesia in dentistry the reader is referred to the monographs of Thiesing, Seitz, and Laewen.

The introduction of suprarenin for local anesthesia in dental operations was of incomparable value. Dentists have accepted the technic as described by the author without change. They have studied the method along anatomical lines and have occasionally added to their equipment instruments better suited to their cases. The amount of space given to local anesthesia in the dental literature of late years is evidence of the importance of this method to this specialty. In this work the literature is referred to only so far as it concerns the physician. To those who are particularly interested the important work of Buente and Moral and the monographs of G. Fischer and Seidel can be recommended.

The Innervation of the Teeth.—The pulp and peridental membrane of the upper jaw as well as the labial side of the periosteum of the alveolar process and the gums are innervated by branches of the infraorbital nerve (Fig. 102). These parts are supplied by branches from the main trunk, partly before entering the bony canal and partly after entering this canal, and are distributed to the bone, alveolar process, or mucous membrane between the antrum of Highmore and the anterior wall of the upper jaw (anterior, median, and posterior-superior alveolar nerves), freely anastomosing with the superior dental plexus. The superior, posterior, and median alveolar nerves (Fig. 102, 2, 3) are located in the beginning on the

tuberosity of the maxillary bone and penetrate the upper jaw in the region of the third molar tooth behind the attachment of the zygomatic process. The labial portion of the gums is also innervated by the end branches of the infraorbital nerve after emerging from the infraorbital foramen. The hard palate, the lingual side of the gums and periosteum are innervated

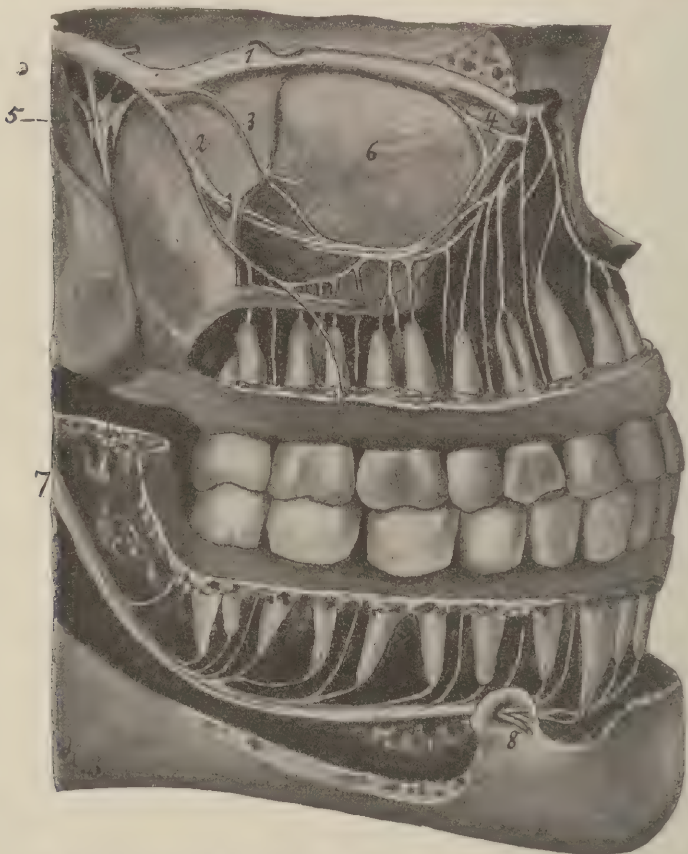


FIG. 102.—Innervation of the teeth. (Partly from Spalteholz.) The lateral wall of the orbit, the outer bony layer of the lower jaw, and parts of the anterior wall of the upper jaw have been removed. 1, infraorbital nerve; 2, branches of the superior-posterior alveolar nerve; 3, branches of the superior-median alveolar nerve; 4, branches of the superior-anterior alveolar nerve; 5, sphenopalatine ganglion and palatine nerves; 6, mucous membrane of the lateral wall of the antrum; 7, inferior alveolar nerve; 8, mental nerve.

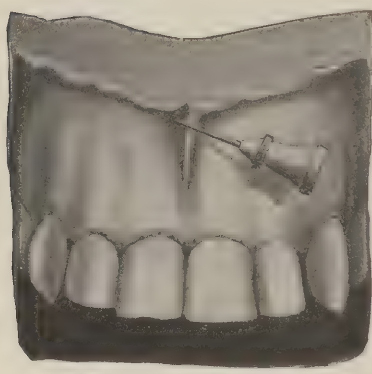
by the anterior palatine nerve which emerges from the major palatine foramen above the third molar tooth and is distributed to the soft parts overlying the hard palate (Fig. 61, page 220); also from the end branches of the nasopalatine nerve which emerges anteriorly from the incisive foramen. The pulp and peridental membrane are not innervated by these nerves.

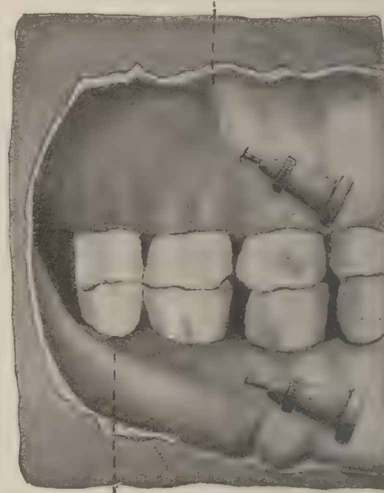
The teeth of the lower jaw are innervated in large part by the inferior alveolar nerve which passes into the bone at the lingula (Fig. 102). This nerve gives off many branches within the bony canal forming the inferior dental plexus immediately underlying the roots of the teeth (not shown in Fig. 102). The pulp and peridental membrane are supplied by the dental rami and the gums by gingival branches which penetrate the bone. A larger branch, known as the mental nerve, leaves the bone through the mental foramen which is situated beneath the first and second biscuspid teeth. The smaller portion of the nerve contained within the bone innervates the canine and incisor teeth. The mental nerve supplies the skin of the chin and the skin and mucous membrane of the lower lip. The lingual side of the gums and periosteum are innervated entirely by the lingual nerve (rami isthmi faucium and sublingual nerve). In the median line the inferior alveolar, mental, and lingual nerves overlap one another more or less. It is also to be observed that the buccinator nerve to some extent innervates the labial side of the gums of the last molar tooth.

Methods to be Used in Operations upon the Upper Teeth.—It is important to know that the dental plexus, formed from the nerve fibers, lies above the roots of the teeth just below the thin anterior and lateral wall of the upper jaw where they can be readily anesthetized, and that the posterior-superior alveolar nerves are just beneath the mucous membrane of the tuberosity of the maxilla where they can be injected before entering the bone, for which reasons the injections of the labial side are by far the most important in operations on the upper jaw. The technic of this injection has undergone characteristic changes in the course of time. One of the first publications in reference to cocaine anesthesia for the extraction of teeth was that of Witzel. In 1886 he injected the fold of mucous membrane high up in the jaw, at its point of reduplication, using a 20 per cent cocaine solution, which was the one most commonly used at that time. Later, when much weaker solutions were used for injection, the dilution exerted less distal effect upon the nerves in the bones, and it became necessary to infiltrate the gums, periosteum, and alveolar process surrounding the tooth to be extracted with cocaine solution. This procedure is not necessary today because we have solutions equally as effective as those containing 20 per cent cocaine, for which reason we can again return to the simple technic of Witzel.

The injections on the anterior surface of the jaw are made in the following manner: The lip and cheek are drawn away from the upper jaw so that the mucous membrane at the point of reduplication forms a right angle with the alveolar process. The syringe is held horizontally, the needle is inserted in a horizontal direction into the reduplicating fold above the roots of the teeth between the mucous membrane and the periosteum (Fig. 103). For rendering the incisor and canine teeth insensitive the point for injection lies next to the frenum; for the biscuspid and first molar teeth, above the roots behind the attachment of the zygomatic process under the mucous membrane covering the maxillary tubercle (Fig. 104).

In case it is desired to anesthetize one tooth, the needle is passed from a point corresponding to the tooth in front to the tooth behind the one to be anesthetized. In case several teeth of the upper jaw are to be rendered insensitive a strip of tissue should be injected continuously from the points mentioned as far as the maxillary tubercle of the same side, injections being carried out from 1, 2, or 3 points. Following the injection the reduplicating fold swells. Immediately upon the withdrawal of the needle the point of injection should be closed with the finger and the anesthetic distributed over the anterior surface of the upper jaw by light massage. The most suitable anesthetic for this purpose is a 2 per cent novocaine-suprarenin solution, or, according to Fischer, a 1.5 per cent solution; for one or two teeth 2 to 3 cc will be necessary, for the entire half of the





FIGS. 103 and 104.—Submucous injections for the extraction of teeth.

upper jaw 5 to 10 cc should be used. For the extraction of many teeth it is advisable to inject the anterior surface of the jaw and maxillary tubercle from the cheek, as was described on page 253. Anesthesia is complete in about five minutes, very rarely sooner, but sometimes later, and consists in complete anesthesia of the labial portion of the gum and periosteum in the region of the tooth or the entire half of the upper jaw, depending upon the extent of the injection. There will also be complete anesthesia of the pulp and peridental membrane. This injection alone is sufficient for operations upon the pulp and dentin, also for the removal of roots and other operations upon the anterior surface of the alveolar process. The end branches of the infraorbital nerve outside of the bone are readily made insensitive if they are directly surrounded by the anesthetic solution.

For the extraction of the upper teeth it is necessary to anesthetize the lingual side of the gums and periosteum. For the extraction of a single tooth 1 cc of a 2 per cent novocaine-suprarenin solution should be injected beneath the hard palate adjoining the diseased tooth. For anesthetizing the entire half of the hard palate in the extraction of many teeth, see page 220. The blocking of the entire maxillary nerve should be considered when operations for suppurative processes of the alveolar process would render the injection in its immediate neighborhood dangerous. Injections for dental operations at the base of the skull are otherwise unnecessary and are not to be recommended for dental work owing to the occurrence of hematomata.

Operations Upon the Teeth of the Lower Jaw.—Injections under the mucous membrane of the alveolar process of the lower jaw can only be successfully performed in connection with the incisor and canine teeth. Posteriorly the bone is much too thick for the anesthetic to exert its effect upon the nerves of the pulp, and lingual injections are only made with difficulty. For these reasons it is advisable to block the alveolar and lingual nerves at the lingula (page 226), in this way producing complete anesthesia of both sides of the gums and periosteum of the bone and the pulp as far forward as the canine tooth. In operations upon the last molar tooth it is advisable to make additional injections into the labial side of the gum so as to block any branches from the buccinator nerve. In connection with operations upon the incisor teeth, which are doubly innervated by the overlapping of the inferior alveolar nerve, it is advisable to use a second injection besides that at the lingula, which has been described by G. Fischer as follows: The lower lip is drawn out and the needle is inserted in the fold of reduplication beneath the canine tooth and passed along the anterior surface of the lower jaw to the mental fossa. This fossa usually contains numerous foramina which permit the injected fluid to reach the interior of the jaw. Injection is made during the entire passage of the needle, but the bulk of the solution, about 1 cc of a 2 per cent novocaine-suprarenin solution, is injected in the region of the mental fossa. When bilateral extractions or operations are to be performed the lingula is injected on both sides, which will, of course, render the injection of the anterior surface of the lower jaw unnecessary.

The fear expressed by Buente and Moral of a disturbance of salivary secretion due to the blocking of the lingual nerve has never been reported, nor has injury to a patient's tongue anesthetized in this way been observed, if they have been previously cautioned. It might be stated that the above method of anesthesia for the entire alveolar process of the upper and lower jaw, either unilaterally or bilaterally, should always be the anesthetic of choice in all other operations upon the alveolar process.

A few words may be said regarding secondary hemorrhage following the use of suprarenin in the extraction of teeth: Personally, in over 1000 extractions the author has never experienced this complication and does not believe that suprarenin can cause a serious secondary hemorrhage which would not have occurred without its use; the hemorrhage, if it

occurs, has been merely delayed by the suprarenin. Secondary hemorrhage following the extraction of teeth can be prevented if the alveolar process is packed with iodoform gauze for a day or two, as has been advised by Roemer. From a surgical stand-point this would seem to be the correct way of handling these cases. Where there are large cavities left in the alveolar process after extraction, packing must naturally be done. Today the majority of dentists take the stand that general anesthesia should not be used for dental operations. This question has been investigated by Wolfram in the various German dental institutions where local anesthesia is taught, and he found that general anesthesia was very rarely used. Knowledge of the application of local anesthesia is one of the leading questions of the day. The only general anesthetic which enters into competition with local anesthesia for the short and simple operation of extraction of a tooth is the ether or ethyl chloride ("rausch") drunk, as there is practically no danger associated with this form of anesthesia. In cases that are more or less complicated, that require more than a minute for their performance, and that can be better carried out slowly, there is no general anesthetic which compares with local anesthesia. The extraction of many teeth under ether, chloroform, or ethyl bromide cannot be countenanced by the physician.

OPERATIONS ON THE PALATE. NASOPHARYNGEAL FIBROMATA.

Anesthesia of the soft and hard palate from 4 points of entrance for the needle was described on page 220. For a simple incision, infiltration of the proposed line of incision with 0.5 per cent novocaine-suprarenin solution is suggested. The removal of the hard palate requires a bilateral blocking of the maxillary nerve. Once again the most cautious use of suprarenin is advised in plastic operations on the palate. The suprarenin anemia simplifies this operation to such an extent that it is scarcely permissible to dispense with it, as has already been stated on page 238 in reference to plastic operations in general; the operator must guard against nutritive disturbances in the flap by the cautious use of suprarenin.

[It is advisable in making these injections to use at most but half the quantity of suprarenin that is usually advised for operations in general, for which reason the solutions should not be prepared from the tablets. —Ed.] In other operations upon the palate this precaution is unnecessary. Extirpation of nasopharyngeal fibromata has assumed an entirely different phase since the introduction of local anesthesia and suprarenin anemia; they can now be removed with practically no hemorrhage. Some cases in which a tumor of this nature was removed under local anesthesia by first performing a temporary resection of the upper jaw according to the method of Kocher are described on page 249. Simple cases having a definite pedicle extending from the base of the skull can readily be completed by incising the soft palate. Local anesthesia with suprarenin anemia limits the indications for preliminary operations in complicated cases.

This may be explained by citing a history: July 5, 1904, a man, aged eighteen years, had a hard fibroma attached by a broad base to the base of the skull in the nasopharyngeal space. The operation was begun for psychic reasons under general anesthesia with the head dependent. The hard and soft palate were infiltrated with a 0.1 per cent cocaine solution with the addition of suprarenin; general anesthesia was then discontinued. The soft palate was split in the middle line without hemorrhage. Under guidance of the finger in the nasopharyngeal space a long needle was passed through the left nasal opening to the base of the tumor and the same solution was injected. After a few minutes the tumor was removed with curved scissors without hemorrhage. The palate was closed by suture, the nasopharyngeal space and nose were tamponed, no secondary hemorrhage following, the healing being very prompt. In other cases the author has removed large nasopharyngeal fibromata in this manner; in these cases, of course, 0.5 per cent novocaine-suprarenin solution was injected instead of the cocaine solution.

OPERATIONS UPON THE TONGUE, FLOOR OF THE MOUTH, AND TONSILS.

The anterior two-thirds of the tongue and the floor of the mouth are innervated by the lingual nerve, which can be readily blocked by injections at the lingula (page 226). The posterior portion of the tongue, tonsillar region and the pharynx are supplied by the glossopharyngeal nerve; the soft palate and anterior portion of the hard palate are supplied by the maxillary nerve. The region about the epiglottis is supplied by the superior laryngeal nerve.

Anesthesia of the tongue and the floor of the mouth by blocking the lingual nerve does not produce the important suprarenin anemia, for which reason in all operations upon these parts, as well as the palate and pharynx, infiltration and circuminjection are necessary.

Hirschel has recently reported a method of blocking the glossopharyngeal and vagus nerves at the base of the skull. He inserts a needle between the maxillary articulation of the lower jaw and the mastoid process, passing the styloid process in the direction of the occipital condyle to a depth of 3 to 4 cm. and injects in this region 10 to 15 cc of a 2 per cent novocaine-suprarenin solution. The glossopharyngeal, vagus and accessory lie near one another at the base of the skull in a connective-tissue sheath, which includes the internal jugular vein and internal carotid artery. A successful blocking of the glossopharyngeal nerve is readily recognized by a paralysis of the recurrent laryngeal and the accessory nerves. This method of Hirschel remains to be tested as to its certainty and freedom from danger. In operations in the pharynx and region of the tonsil the local circuminjection should be performed owing to the effect of the anemia produced. Sensation in these parts is not very pronounced; at any rate the failure to block the glossopharyngeal and vagus nerves has never been reported to cause any disturbance on the part of patients in excision

of carcinoma of the tonsils or pharynx, either through the neck from without or following a temporary separation of the jaw. Whether the trunk of the vagus, after branching of the auricular nerve, possesses pain sense is very questionable. The point of most importance, however, is the anesthetizing of the operative field to such an extent as to permit of the free exposure of the pharynx. Pharyngeal reflexes can be allayed by applications of alypin-suprarenin solutions. As soon as the pharynx becomes accessible the anesthesia can be completed by submucous injections. The blocking of the superior laryngeal nerve will be described in the following chapter.

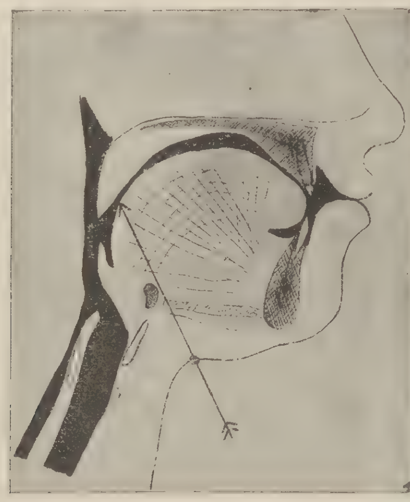


FIG. 105.—Infiltration of the base of the tongue.

Operations Upon the Tongue Without a Preliminary Operation.—We will take as an example the removal of a small tumor from the lateral portion of the tongue or from its anterior portion or the removal of sections for microscopical examination. For this purpose a small wheal is injected upon the surface of the tongue with a 0.5 per cent novocaine-suprarenin solution. A needle is then passed through the tongue as far as the mucous membrane of its under surface. This tract is infiltrated with the same solution, after which a traction suture is passed through the anesthetized area so the tongue can be drawn forward and fixed. The diseased area is now circularly injected with 0.5 per cent novocaine-suprarenin solution, after which the tumor can be removed without pain or hemorrhage and the wound sutured.

In case the disease is more extensive, this circuminjection is dispensed with and in its place the entire tongue and floor of the mouth are rendered anesthetic and anemic by the following procedure: One point of entrance is marked by a wheal under the chin in the median line immediately over the hyoid bone. The left finger is then passed above the epiglottis to

the base of the tongue in the same manner as when performing intubation. From this point a long needle is passed toward the tip of the finger infiltrating this area (Fig. 105); the needle is then passed in various directions, first in the median line, then more toward the right and left, and finally as far laterally as the lower jaw. This separates the tongue and floor of the mouth from their blood and nerve supply by an infiltrated barrier. For this injection 50 cc of 0.5 per cent novocaine-suprarenin solution is necessary. The tongue and floor of the mouth will become insensitive and anemic. The tongue can now be drawn out and the operation completed. Injections at the lingula are not necessary.

Minor Operations on the Floor of the Mouth.—Small cysts (ranula) or benign tumors of the floor of the mouth should be injected from without from a point under the chin. The needle is guided by the left index finger placed in the mouth and the area is injected with 0.5 per cent novocaine-suprarenin solution. Large cysts in the median line of the floor of the mouth which cause a bulging in the chin region are better extirpated from without. This can be done after a bilateral blocking of the lingual nerve at the lingula. It will then only be necessary to circuminject the operative field in the usual manner.

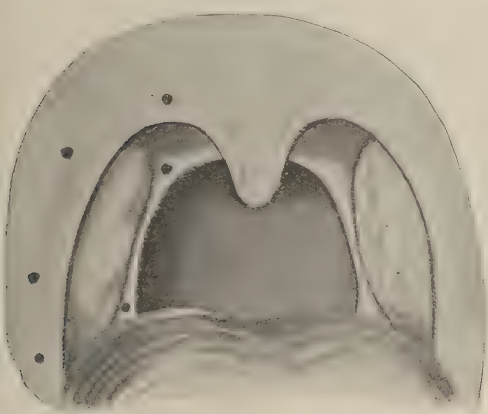


FIG. 106.—Points of injection for tonsillectomy. (After Heymann.)

FIG. 107.—Circuminjection for median section of the jaw. 3, point of injection over the hyoid bone.

Local Anesthesia for Tonsillectomy.—Anesthesia for tonsillotomy is usually not necessary, but the operation of tonsillectomy, as performed today by the specialists in this field, requires anesthesia. For anesthesia of this region the anterior and posterior pillars of the fauces should be infiltrated from several points (Fig. 106). This area as well as the tissues lateral to the tonsils is freely infiltrated with 10 to 15 cc of a 0.5 novocaine-suprarenin solution. For anesthesia of the pharyngeal tonsil, Ruprecht advises the application of tampons saturated with 10 per cent alypin-

suprarenin solution. These applications are made by means of a sound passed through the nasal canal.

Radical Operations for Carcinoma of the Tongue, Floor of the Mouth, and Tonsillar Region.—The anesthesia is begun by a bilateral blocking of the lingual and inferior alveolar nerves at the lingual (page 226) and completed by an injection as is shown in Fig. 105. In case the operative field extends to the pillars of the fauces, tonsillar region, or lateral pharyngeal wall, these areas must be injected from below and behind with 0.5 novocaine-suprarenin solution. A blocking of the maxillary nerve is, as a rule, not required. It will now be necessary to anesthetize the parts

FIG. 108.—Excision of the base of the tongue and left tonsil for carcinoma. The lower jaw is cut, the tongue drawn to the right. The epiglottis is seen in the depths of the wound at the completion of the operation.

for the preliminary operation, which consists of a transverse splitting of the cheek as described on page 244. The method of circuminjection for a median section of the lower jaw is shown in Fig. 107. Point 3 indicates where the needle must be passed for infiltrating the base of the tongue. For the circuminjection 30 cc of a 0.5 per cent novocaine-suprarenin solution is necessary.

The operation can now be performed without pain or hindrance from hemorrhage. Peuckert and the author have reported 13 cases of excision of the tongue, extirpation of the floor of the mouth in connection with resections of portions of the lower jaw, and extirpation of carcinoma of the tonsils, with this method of anesthesia. Fig. 108 shows one of our

patients during the operation. What has been said already with reference to resections of the upper jaw holds for operations in the mouth; that is, local anesthesia has changed completely the appearance of these patients during operation. It has simplified the operation, which can be carried out in a much cleaner and safer manner and with less danger of aspiration pneumonia. We had only 2 postoperative lung complications in the 13 patients operated upon under local anesthesia in connection with suprarenin anemia. A large number of cases of carcinoma of the mouth, in which formerly a median section of the lower jaw was necessary as a preliminary operation, can now be operated upon with as much ease by the simple section of the cheek.

CHAPTER XII.

OPERATIONS ON THE NECK.

The anterior surface of the neck is an excellent region for local anesthesia. With the exception of phlegmons, there are few operations on the neck where it is not superior to general narcosis and therefore the method of choice.

Bier and Madelung have pointed out the possibility of performing major operations of all kinds upon the neck under local anesthesia. Bier lays special stress upon its use for thyroidectomy and extirpation of the larynx. Madelung states that he has for many years preferred a 1 per cent novocaine-suprarenin solution for local anesthesia in all major operations, such as thyroidectomies, removal of glands, resection and extirpation of the larynx, pharynx, and esophagus.

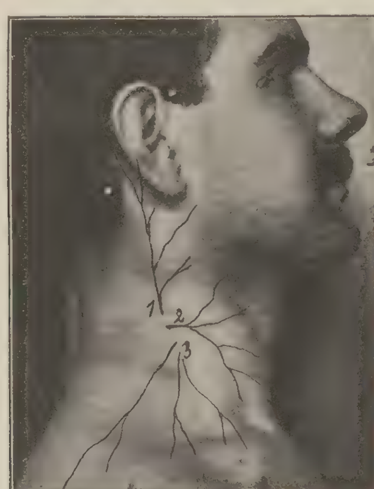


Fig. 109.—The sensory innervation of the neck: 1, auricularis magnus; 2, cutaneus colli; 3, supraclavicular nerves.

While formerly anesthesia in face operations was practised, as a rule, by careful deep and superficial circuminjections of a field of operation, recently preference has been given to nerve blocking in neck operations. Circuminjections are necessary only for the purpose of supplementing nerve blocking and for anesthetizing small superficial areas.

The soft structures of the front of the neck are supplied by the anterior branches of the second, third, and fourth cervical nerves, whose terminal

branches, the auricularis magnus, cutaneus colli, and supraclavicular come to the surface at the posterior edge of the sternocleidomastoid muscle. Pain in the larynx and esophagus is probably transmitted only through the cervical nerves (Fig. 109). On the other hand it is quite improbable that any pain is transmitted from the neck by the vagus. The mucous membrane of the esophagus is devoid of any sensibility.

A subcutaneous and subfascial injection along the posterior edge of the sternocleidomastoid merely renders the skin of the neck insensitive, which practically is of no value. Complete anesthesia of the region supplied by the specified nerves is only obtained by anesthetizing the nerves as they leave the spinal column.

Fig. 110.—Line of the transverse processes of the neck. *a* and *b*, points of entrance for the needle.

Kappis recently reported that he had succeeded in blocking the cervical nerves just as they leave the foramina of the cervical vertebræ, and thus was able to anesthetize the whole cervical and brachial plexus. He introduces the needle from the back, laterally along the spinous processes to the transverse processes of the cervical vertebræ and even beyond them for another 1 to 1.5 cm. forward, and injects 1.5 per cent novocaine-suprarenin solution. The cervical plexus can be reached easier from the side. Following Heidenhain's suggestion the author for years has carried out the injection in the following manner: The needle is introduced at two points on the side of the neck in the line of the transverse processes and all of the tissue layers from the skin down to the transverse processes

are infiltrated with 0.5 per cent novocaine-suprarenin solution. Circum-injection of the operative field follows.

Haertel and Geiger have simplified the blocking of the cervical plexus. Haertel points out the fact, as shown by the following scheme, that there are isthmic places in the cervical plexus through which pass the entire innervation of the plexus.

C_2 C_3	N. occipitalis minor N. auricularis magnus N. cutaneus colli	upper group
C_3 C_4	Nn. supraclaviculares ant. Nn. supraclaviculares med. Nn. supraclaviculares post.	lower group

It is necessary therefore to inject at two points only in order to block the entire plexus: (1) For the upper group at the point of union of the C_3 with the anastomosis of C_2. This point corresponds anatomically to the point of exit of the third cervical nerve in front of the transverse process of the third cervical vertebra; (2) for the lower group at the point of union of C_4 with the anastomosis with C_3. This point corresponds to the point of exit of the fourth cervical nerve in front of the transverse process of the fourth cervical vertebra. Since the transverse processes of the third and fourth cervical vertebræ are only 2 to 3 cm. apart, the injections, as suggested by Geigers, may be made through a single puncture. According to the author, it is not always possible or necessary to pass the needle with anatomical accuracy down to the two points mentioned and by contact with the nerves to elicit characteristic paresthesias. It is necessary to infiltrate with the solution only the tissues in the region of the transverse processes of the third and fourth cervical vertebræ which contain the plexus in order to block the entire plexus. The author gives the following method of injecting the plexus. The head is bent slightly backward and turned toward the opposite side. The line of the transverse processes, which extends from the posterior border of the mastoid process above to the transverse process of the sixth cervical vertebra (tuberculum carotideum) below is marked on the surface. The line is extended to the clavicle and subdivided into three equal parts. A wheal is made in the skin at the junction of the upper and middle thirds of this line, which marks the level of the third and fourth cervical vertebræ. A needle detached from the syringe is introduced at this point and passed in perpendicularly until it comes in contact with the next lying transverse process. It is absolutely necessary that the transverse process be felt with the point of the needle. Without introducing the needle any deeper the point is directed a few mm. backward and downward. Should no blood escape from the needle, 40 to 50 cc of a 0.5 per cent novocaine-suprarenin solution are injected. At first a portion of this is injected slowly and carefully, then after a few minutes' wait the remainder. Should blood or bloody fluid escape from the needle, no injection should be made until the point of the needle has been moved and the escape of blood ceases. Fig. 111 is a schematic cross-section of the neck, showing the

needle down to the transverse process. As a rule the needle passes through the posterior border of the sternocleidomastoid muscle. Haertel draws this muscle forward with the fingers when the transverse processes will be only about 1 cm. beneath the skin. It is unnecessary to use more concentrated solutions, since blocking of the plexus is complete within a few minutes after the use of a 0.5 per cent solution, and lasts long enough for one to perform almost any operation. Unfortunately, blocking of the cervical plexus has been followed by dangerous secondary effects, mostly collapse, at times with a fatal result. This fact has already been mentioned

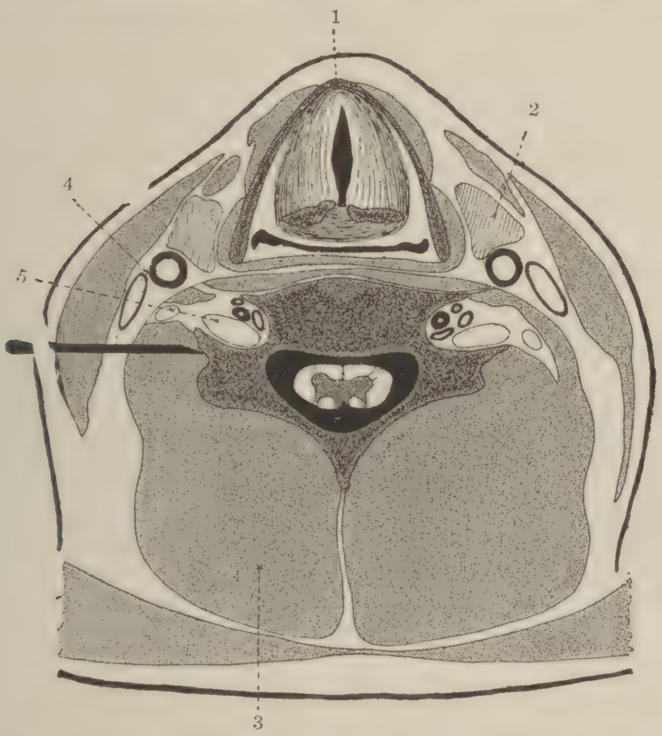


FIG. 111.—Schematic cross-section of the neck showing the needle down to the transverse process.

on page 121. The author has performed puncture of the transverse processes of the cervical vertebræ formerly in a somewhat circumstantial way since 1909. During this time he has performed 673 strumectomies under local anesthesia with 2 accidents of this kind, 1 in 1919 and 1 in 1920. Aside from these, the author has observed no secondary effects from local anesthesia in this region. Haertel is of the opinion that secondary effects may be prevented if the needle be not introduced deeper than the transverse processes, and particularly not in front of them. The author considers that quite probable since these effects were observed first during the last

years when the needle was introduced in front of the transverse processes. Formerly, when the needle was introduced only down to the transverse processes, nothing of the kind happened. Obviously it is not a question of the dose of novocaine in these cases but one of the needle penetrating vertebral vessels, which in fact may be done very easily in front of the transverse processes, or of its entering the vertebral foramen, or perhaps coming in contact with the vagus nerve (see page 122). The author does not advise giving up blocking of the cervical plexus, but for one to observe carefully the necessary technic in its use, since it is a very simple and valuable procedure which makes possible the performance of all operations on the neck. Blocking of one side produces anesthesia of the lateral and inferior triangles as far forward as the midline, while blocking of both

Fig. 112.—Circuminjection for operations on the neck.

sides takes in the entire circumference as well as the soft parts of the chest and back as far as they are supplied by the supraclavicular nerves. The anesthesia includes all of the organs of the neck. If the field of operation is limited strongly to one side, no injection beyond the unilateral blocking of the plexus is required, but in case the field extends to and beyond the midline that area must be circuminjected unless both plexuses are blocked. The performance of special typical operations need be gone into but briefly.

The Extirpation of Lymph Glands.—The tissues about single circumscribed movable gland tumors can be injected in pyramid form as shown in Fig. 37, page 198. Injection beneath the tumor is facilitated by raising it up with the left hand. The plexus should always be blocked in the

removal of large gland masses. Some difficulty may be experienced if the glands develop posteriorly, thus covering the transverse processes. In such cases it may be necessary to reach the transverse process from behind after the method of Kappis. Operations on lymph glands beneath the angle of the lower jaw and in the submaxillary salivary gland usually extend into regions supplied by the third branch of the trigeminal nerve, in which case it will be necessary, in addition to blocking the cervical plexus, to block the inferior dental and lingual nerves or to infiltrate the floor of the mouth directly. Furthermore, it will be necessary to infiltrate subcutaneously along the lower border of the inferior maxilla should the operation extend that far.

FIG. 113.—Removal of the left submaxillary salivary gland, submental and lymphatics of the neck under local anesthesia for carcinoma of the base of the tongue and left tonsil. The left jugular vein was resected.

FIG. 114.—Dissection of the neck for complete removal of the lymphatics of the neck and the submaxillary salivary gland under local anesthesia for carcinoma of the tongue.

For typical removal of the fat of the neck with all of the lymph glands lying beneath, the angle of the lower jaw and along the vessels, and the submaxially lymph gland, preliminary to removal of carcinoma of the lower lip, or of the floor of the mouth, the cervical plexus of both sides of the neck should be blocked and the subcutaneous tissues along the lower border of the inferior maxilla should be infiltrated from one side of the neck to the other with infiltration of the floor of the mouth. For all of these injections 0.5 per cent novocaine-suprarenin solution should be used. Instead of infiltrating the floor of the mouth the lingual nerve on both sides may be injected. It is interesting to know that resection of the vagus, which does not come in contact with the anesthetizing solution,

causes no pain whatsoever. Fig. 113 shows one of the author's patients and Fig. 114 one after a bilateral operation of this kind. The same technic is employed in suprahyoid pharyngotomy. Ligation of the arteries of the neck or other operations on the large bloodvessels require unilateral blocking of the cervical plexus. All other injections are superfluous.

Thyroidectomy.—The simplest and best procedure in operations on the thyroid is bilateral blocking of the cervical plexus. No other injections are necessary. In unilateral operations the plexus may be blocked on one side only, the field of operation toward the opposite side limited by deep and superficial circuminjection about the isthmus. The author limits such circuminjections to the enucleation of isolated tumors of the isthmus. In all other cases the author follows the method of

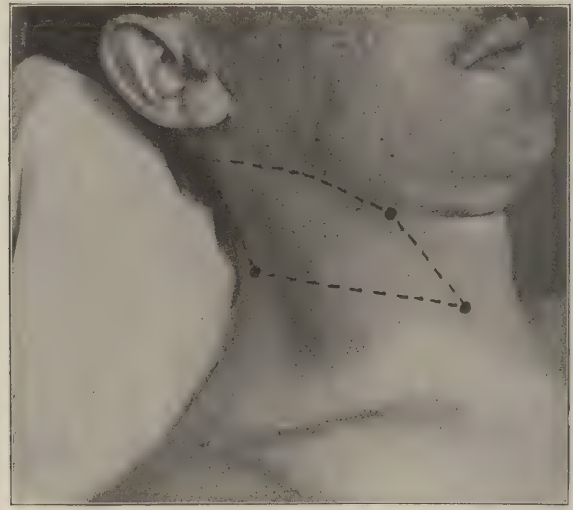


Fig. 115.—Injection for ligation of the superior thyroid or external carotid artery.

Geiger and blocks the plexus on both sides, thereby rendering the entire field of operation anesthetic with a much smaller amount of novocaine (80 cc 0.5 per cent solution). This simplifies and improves materially the method of producing anesthesia in operations on the thyroid. The advantages of local anesthesia over general narcosis in thyroidectomy are quite obvious. There is no anesthetist to obstruct the field of operation and disturbing vomiting under local anesthesia is a very rare exception. It is important to be able to have the coöperation of the patient to prevent injury to the recurrent laryngeal nerve. General narcosis is particularly unpleasant and hazardous in tracheal stenosis. Some surgeons (Kausch) prefer narcosis in Basedow's disease on account of the excitability of some of these patients. It is true that some of them are not good subjects for local anesthesia, but this is by no means the rule, since the majority of

FIG. 116.—Thyroidectomy with excision of the right lobe and isthmus.

FIG. 117.—Thyroidectomy with excision of the right lobe and isthmus.

patients with Basedow's disease are suitable, and for them local anesthesia is the least disturbing measure. There are patients with Basedow's disease who, when brought into the operation room, are so excited that one is at a loss to know what to do. It is better then to send the patient back and wait for a more favorable time. Occasionally the author has had ether given to light narcosis during which the injections were made and then the narcosis discontinued, the operation being completed, as a rule, without further disturbance.

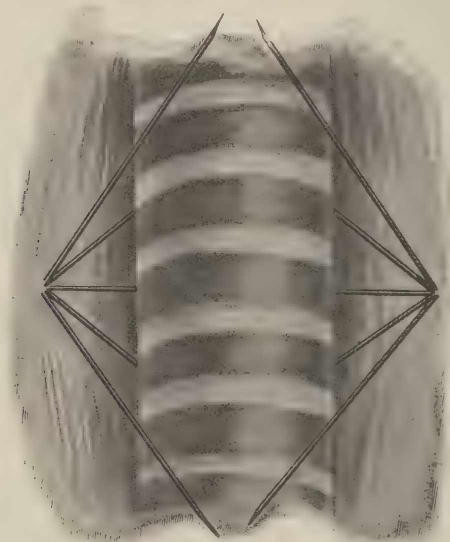


FIG. 118.—Method of injection for tracheotomy. (Most.)

Tracheotomy.—In performing tracheotomy two entrance punctures should be made to the right and left of the trachea, and from these points the field of operation is injected in a trough-like manner, according to Fig. 38 (page 198). A diagram illustrating this injection, drawn by Most, is shown in Fig. 118. It is very important to avoid general anesthesia in patients suffering from stenosis of the trachea, for which reason it is advisable to use local anesthesia. Young children, however, are often so restless that it is impossible to get on without some general anesthesia. In emergency cases it is well to infiltrate along the line of incision.

OPERATIONS IN THE LARYNX.

Repeated reference has been made to the inestimable benefit to the field of laryngology by the introduction of cocaine. The mucous membrane of the larynx is usually anesthetized by swabbing it with a 10 to 20 per cent cocaine solution, and in doing this it is well to prevent the excess of

the cocaine solution from running into the trachea and esophagus. After the swabbing, the patient should be permitted to cough and expectorate. The cocainizing should be done repeatedly in order to arrest the reflexes of the mucous membrane of the larynx long enough for the patient to bear the introduction of instruments. This is more important than overcoming the sensation of pain, which is evidently very slight in this organ. The swabbing is very disagreeable to the patient, therefore many laryngologists prefer to apply a small quantity of the cocaine solution to the larynx with a small spraying apparatus made for the purpose or with a syringe. M. Schmidt prefers the syringe because with it the dosage of cocaine can be more accurately controlled. The effect of the cocaine lasts from five to ten minutes and much longer if suprarenin is added. Siefert and Ruprecht report that alypin used in 10 per cent solution with the addition of suprarenin is a splendid substitute for cocaine.

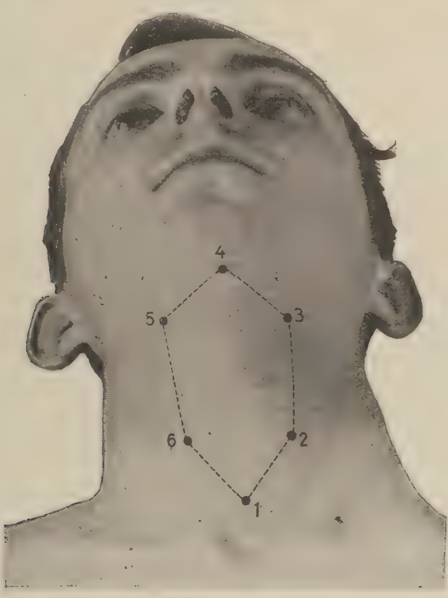


Fig. 119.—Laryngotomy and laryngectomy.

The sensory innervation of the larynx, at any rate that part above the vocal cords, comes through the internal branch of the superior laryngeal nerve. This nerve emerges immediately under the posterior end of the hyoid bone, then runs forward under the anterior border of this bone for a short distance on the thyrohyoid membrane, which it penetrates, sending branches into the mucous membrane of the larynx, the pyriform sinus, and the surrounding mucous membrane of the pharynx. The other two nerves which enter the larynx are essentially motor nerves; they are the external branches of the superior laryngeal and of the recurrent laryngeal.

Efforts to anesthetize the larynx by a bilateral blocking of the internal branch of the laryngeal nerve were unsuccessful until the introduction of suprarenin.

As early as 1903 the author succeeded in obtaining such complete anesthesia that Viereck, a surgeon, was able to curette a tuberculous larynx. Viereck, who continued these experiments, asserts that the anesthesia always extends to the epiglottis and the entire upper part of the cavity of the larynx to the glottis, but that it is not always complete below the glottis. Other favorable reports have been made by Frey, Chevrier and Cauzard, and Kuttner. It is a very simple matter to accomplish this blocking. A needle of medium size is inserted under the skin in the median line, between the thyroid cartilage and the hyoid bone, then into the thyrohyoid ligament. It is directed in this ligament toward the end of the hyoid bone, which has been previously located by the finger. The ligament is infiltrated on both sides with 5 cc of 0.5 or 1 per cent of novocaine-suprarenin solution. The mucous membrane of the larynx immediately becomes anemic in consequence of the contraction of the superior laryngeal artery, produced by the suprarenin. The advantages of this method over intralaryngeal cocainization are considerable; it is more easily and quickly carried out, the anesthesia of the larynx lasts much longer and an overdose of cocaine is prevented. It is surprising, therefore, that it has not long since become a part of the daily work of the laryngologist.

Laryngotomy and Laryngectomy as a result of the use of local anesthesia have become technically very simple operations and narcosis is no longer necessary. Bilateral blocking of the cervical plexuses with infiltration of the thyrohyoid membrane with 0.5 per cent novocaine-suprarenin solution to suspend reflexes are all that is required.

Subhyoid Pharyngotomy.—Subhyoid pharyngotomy requires the same injection as for laryngectomy. Unilateral blocking of the cervical plexus has been of great value in esophagotomy for foreign bodies and in the extirpation of esophageal diverticula.

CHAPTER XIII.

OPERATIONS ON THE SPINAL COLUMN AND THORAX.

The Innervation.—Shortly after the thoracic nerves emerge from the intervertebral foramina of the dorsal vertebræ they send out connecting branches (rami communicantes) to the sympathetic nerves, and then divide into anterior and posterior branches. The latter supply the muscles of the back and innervate the skin to the right and left of the median line. The anterior branches, namely, the intercostal nerves, at their origin run approximately in the middle of the intercostal spaces. Near the angle of the ribs they approach the lower border of the rib above. At first, they lie immediately upon the endothoracic fascia and the pleura; as they approach the angle of the ribs they lie between the external and internal intercostal muscles. Their further course is shown in Figs. 120 and 122. The lumbar nerves lie between the transverse processes of the lumbar vertebræ, in front of the transversalis muscle connecting the transverse processes, and are surrounded by the origin of the psoas muscle. The iliohypogastric and ilioinguinal nerves, which are important nerves supplying the anterior abdominal wall, are derived from the twelfth dorsal and first lumbar, and run like the twelfth intercostal nerve, on the front surface of the quadratus lumborum muscle, then between this and the outer surface of the fatty capsule of the kidney, continuing between the transverse and oblique abdominal muscles.

From the second lumbar nerve, the emerging nerve trunks take such a decidedly downward course and lie so close to the vertebral bodies that they can only be reached by making the injection close to the vertebral bodies.

The intercostal nerves and the first lumbar nerve furnish the sensory nerve supply to the chest wall and abdominal wall, including the parietal pleura and peritoneum.

The middle intercostal nerves do not in the beginning anastomose with one another; the first and second intercostal nerves send branches to the brachial plexus, immediately upon their emergence from the foramina; the twelfth intercostal sends branches to the first lumbar nerve. The segmental innervation of the wall of the chest and abdomen is illustrated in Fig. 123. The intercostal nerves supplying the skin overlap each other to such an extent that, as a rule, the central blocking of a single one of them does not perceptibly alter the sensibility of the skin so that it is necessary to block several of them in order to secure an anesthetic operative field. The overlapping seems to occur to a greater extent from the upper to the lower segments, so that by the central blocking of a number of intercostal nerves, anesthesia of the skin will begin two segments lower than the uppermost injection.

At the upper end of the bony thorax, in the infraclavicular space, at the upper border of the scapula and the axilla, the sensory innervation is supplied by the terminal branches of the cervical and brachial plexus. The supraclavicular nerves lie subcutaneous, crossing the clavicle and the scapular ridge and innervate the skin anteriorly frequently as far as the nipple. The author does not agree with Haertel's statement that the phrenic nerve supplies pain sense to the diaphragmatic pleura, since he has operated on a number of cases of subphrenic abscess and liver echinococcus cysts under blocking of the intercostal nerves and has never found the diaphragmatic pleura or the diaphragm itself sensitive.

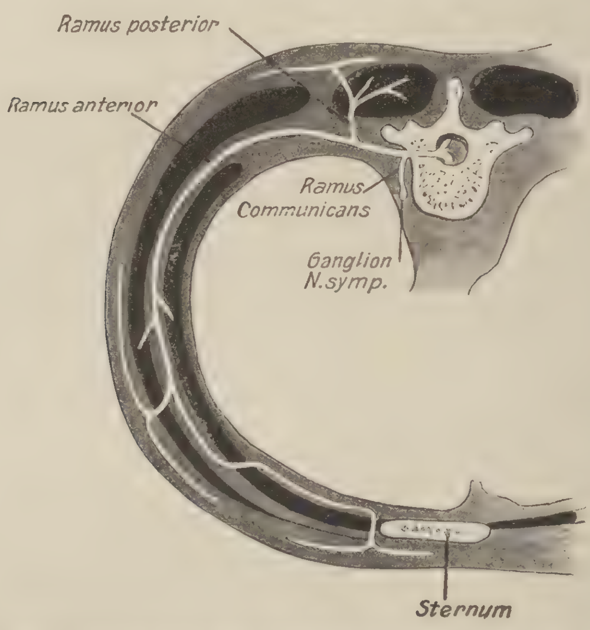


Fig. 120.—Diagram showing the course of the intercostal nerves. (After Corning.)

The diaphragmatic peritoneum was likewise always insensitive even when the rami communicantes were not blocked. Haertel's opinion is also opposed on embryological grounds. The very peculiar course and length of the phrenic nerve are due to the migration of the diaphragm which it supplies. From the first it seems to be a pure motor nerve and these and other parts of the body carry no pain-conducting fibers. The intercostal and lumbar nerves supply sensation to the chest wall and abdominal wall, with the exceptions of the upper and lower borders, together with the parietal pleura and parietal peritoneum. Blocking of these nerves, which may be done at any point in their course, near or remote from the spinal column, leads to anesthesia of the concerned area (intercostal anesthesia).

Lennander's statement that the abdominal organs possess no pain sense is true only to the extent that certain parts of these organs, for instance the walls of the stomach and intestines, are insensitive in a practical surgical sense to cutting, crushing, and burning. In operations, however, after the abdomen is opened there is experienced an indefinite, unlocalizable sense of pain, called "abdominal sensation," even when the abdominal wall and the parietal peritoneum are anesthetic. Abdominal surgery under local anesthesia is possible, therefore, when this "abdominal sensation" can be overcome.

Neumann and Kappis have shown that in the abdomen the sympathetic nerves alone carry these pain sensations. The above rami communicantes nervi sympathici are the paths by which the sensory nerves derived from the sympathetic ganglia and plexuses of the abdominal cavity are carried partly directly and partly through the splanchnic nerves to the spinal nerves, the spinal cord, and the brain. In the pelvis the autonomic pelvic nerve performs this function. Fig. 124, taken from Meyer and Gottlieb in *Experimental Pharmacology* gives a clear picture of the anatomical relations of the individual segments of the spinal cord to the sympathetic nerves and to the abdominal organs. However, it should be remembered that the vagus nerve is not concerned with pain sense in the abdominal organs. By blocking the intercostal and lumbar nerves at their point of exit from the vertebral canal, just before or at their point of junction with the rami communicantes, it is possible to produce anesthesia not only of the walls of the chest and abdomen but also of the organs contained in these cavities. This is called paravertebral anesthesia.

It will be seen from Fig. 124 that the splanchnic nerves receive sympathetic nerve fibers from a considerable part of the abdominal organs. By animal experimentation, Neumann and Kappis have shown that the splanchnic nerves contain pain-carrying fibers and that after they are interrupted a considerable portion of the abdominal organs is insensitive. This applies also to man. It is possible by interrupting or blocking the splanchnic nerves to eliminate abdominal sensation from a large part of the abdominal cavity (splanchnic anesthesia).

After this digression we will return to surgery of the thorax and point out the limitations of local anesthesia. Its applicability is limited essentially to operations on the chest wall, to resection of one or more ribs, to thoracotomy, and to resection of portions of the chest wall for tumors. It is indicated in acute empyema, in abscesses of the lung lying in contact with the chest wall in which the dangers of aspiration would be greatly increased by narcosis, and in the removal of ribs in the treatment of pulmonary tuberculosis, in transpleural operations for subphrenic abscess and echinococcus of the liver. Plastic operations on old empyemas and in total empyema are more difficult under local anesthesia, as the injection of the intercostal nerves is uncertain owing to the overlapping of the ribs and the inclusion of the nerves in the pleural thickening. In these cases the author prefers narcosis.

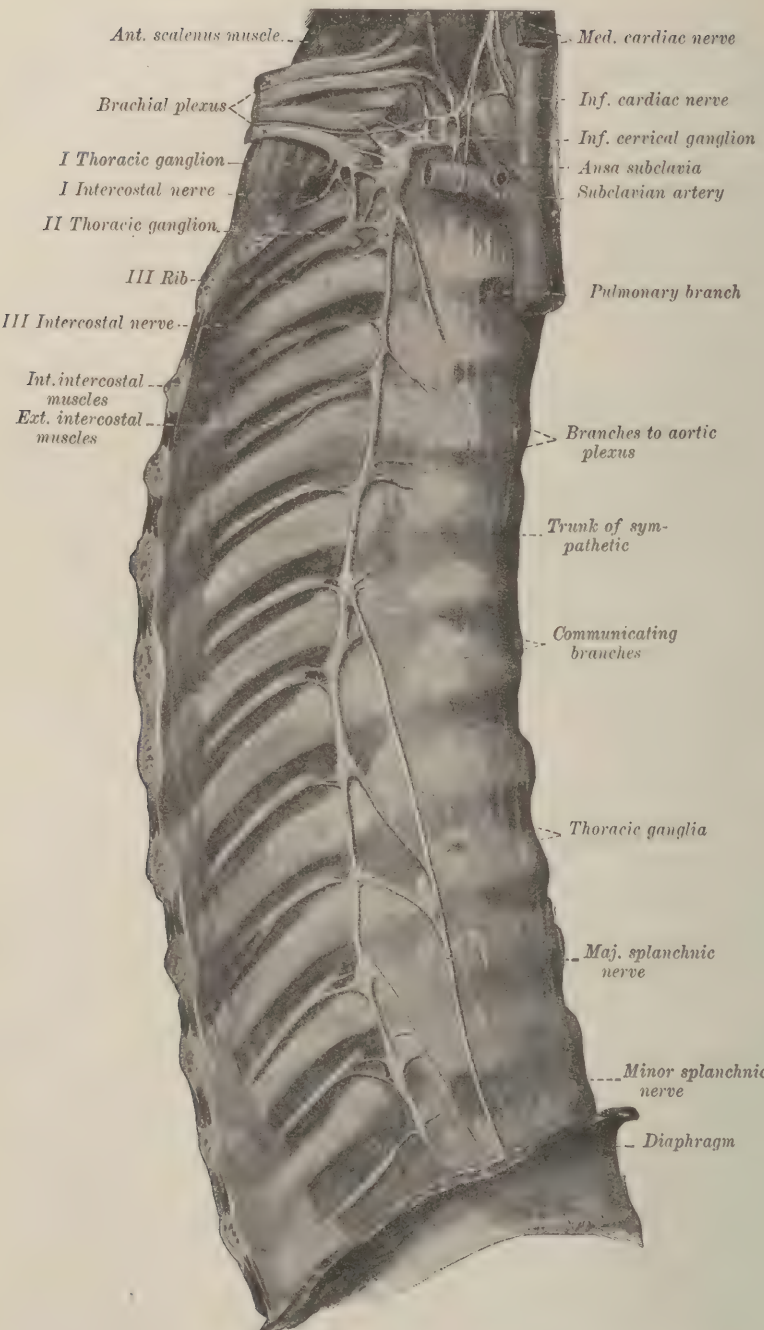


Fig. 121.—Intercostal and sympathetic nerves. (After Spalteholz.)

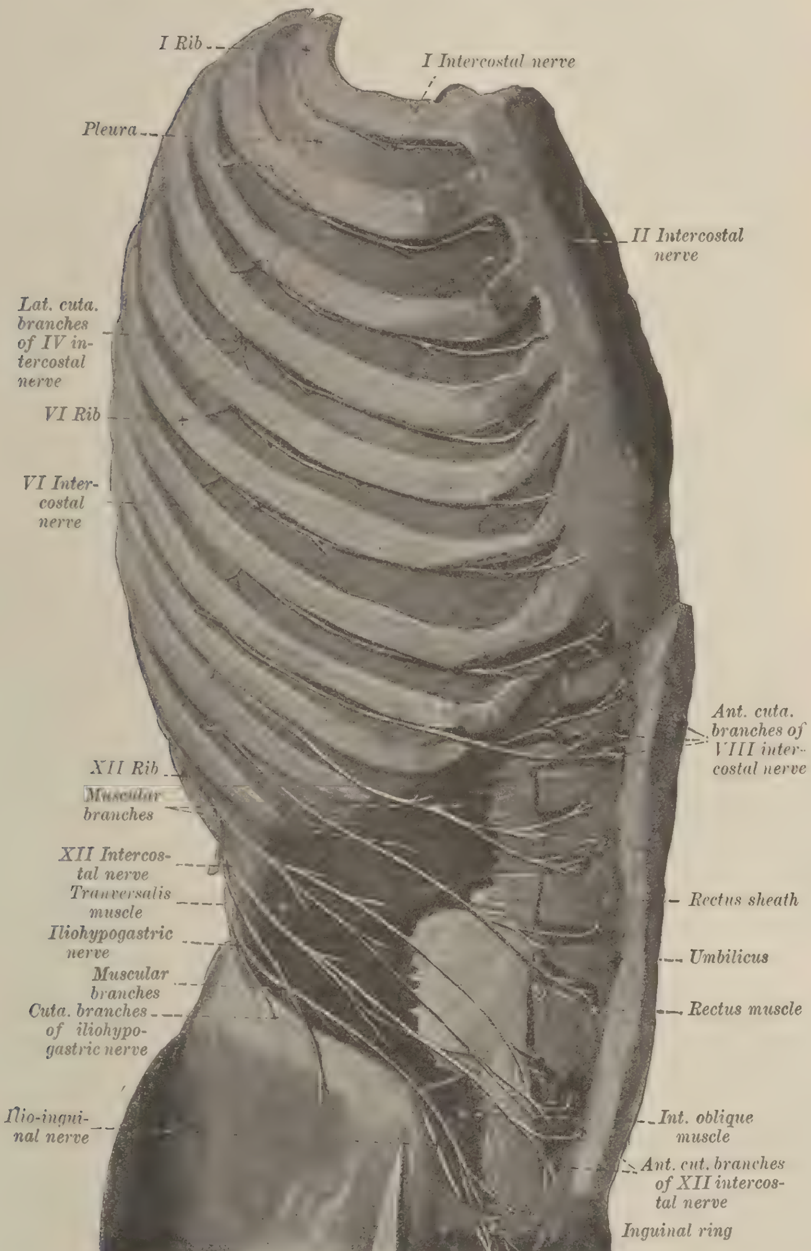


FIG. 122.—Course of the intercostal nerves. (After Spalteholz.) The intercostal and oblique muscles have been removed.

Sauerbruch characterizes operations within the chest under local anesthesia as a technical error, since intrapleural manipulations such as drawing on the root of the lung or compression of the same, or touching the parietal pleura where not anesthetized, causes strained breathing and reflex inhibition of the heart's action and of respiration. The unpleasant secondary effects of opening the pleura and the heaving of the lungs are much less pronounced in the narcotized patient.

Intercostal anesthesia may be used here instead of paravertebral anesthesia, since it is unnecessary to block the nerves immediately at their exit from the spinal column.

Schuhmacher and Kappis were the first to report extensive operations in the thorax under intercostal conduction anesthesia. The technic of blocking the intercostal nerves without the rami communicantes for operations in the thorax and upper part of the abdominal wall is as follows: The patient sits with the body bent forward and the arms crossed in order to spread the scapulæ as much as possible. If the patient cannot sit up, he lies on the side with the back bent, the side to be injected being uppermost. A wheal is made in the skin at a distance of at least 5 cm. from the line of the spinous processes; a long needle is then introduced and a narrow strip of skin parallel with the line of the spinous processes anesthetized by subcutaneous infiltration with a 0.5 per cent novocaine-suprarenin solution, the length of the strip corresponding with the number of nerves to be blocked (Fig. 131).

The injection of the intercostal nerves is begun at the first or the twelfth ribs because these may be easily located without time-consuming measuring and counting. Should one wish to begin at the first rib, a 6 cm. long needle is introduced through the narrow strip of anesthetized skin at the level of the first dorsal spine (Fig. 132). The point of the needle should strike the first rib. This is not difficult in thin individuals but in stout and muscular subjects one must often search for the rib. So soon as the point of the needle comes in contact with the rib it is moved about slightly until the point just clears the lower border of the rib, when the needle is pushed about 0.5 to 1 cm. deeper in a direction toward the midline and somewhat caudad, and the intercostal space infiltrated with 10 to 15 cc of a 0.5 per cent novocaine-suprarenin solution. One is more certain of securing anesthesia by injecting more of a weak solution than less of a strong solution. As the needle is pushed into the intercostal space the injection is begun, as thereby the pleura is crowded out of the way and its puncture prevented. It is unnecessary to search for the nerve with the point of the needle in order to obtain paresthesia. The needle used to inject the first intercostal space is allowed to remain in position while a second needle is used in a similar manner to inject the second space. The first needle is then removed and used to inject the next space while the second needle is in place and so on. [The needle in place affords an excellent guide to the next rib.—Ed.] The injections may proceed from below upward with equal facility. The twelfth rib is always palpable somewhat further laterally and its lower border may

be reached easily with the needle by passing it at the point where a line continued in the direction of the rib crosses the anesthetized strip of skin. The distance of the upper ribs from each other is about 3 cm. and of the lower ribs about 4 cm., but this distance may be diminished correspondingly in deformed chests. The posterior branches of the intercostal nerves are involved by this injection, so that with a relatively small amount of the solution (120 to 150 cc for all of the intercostal nerves of one side) a large area of anesthesia extending from behind forward practically to the midline is obtained within which almost any operation on the thorax or lungs may be performed.

In operations on the upper part of the thorax the branches of the cervical plexus which extend into this region must also be blocked. The supraclavicular nerves may be easily interrupted by injecting at the transverse processes of the cervical vertebræ (page 284), or by subcutaneous infiltration of a narrow strip along the clavicle and the spine of the scapula (Fig. 133). Should the operation extend into the axilla, the brachial plexus must also be blocked. It is necessary to prepare patients for blocking the intercostal nerves in this manner by the use of narcotics and scopolamine, as searching for the ribs with the needle is always accompanied with some pain, however slight, and some inconvenience. The author has seen but one mishap following these injections. Upon making an intercostal injection there occurred suddenly a severe pleurodynia, such as has been observed more frequently in faulty injection of the brachial plexus after Kulenkampf's method and which compelled the postponement of the intended operation. The author has never observed any other similar effect.

Operations limited to small and circumscribed portions of the thoracic wall may be performed with less discomfort to the patient by the simpler method of circuminjection to be described. It is like shooting sparrows with a cannon to use central blocking near the vertebræ for these small operations. Central blocking has greatly increased the indications for local anesthesia in extensive operations, but it is too technical to ever displace the simple and certain circuminjection in suitable cases.

Concerning the use of intercostal injections in operations on the abdominal wall, see the following chapter.

In connection with intercostal anesthesia we must mention here paravertebral anesthesia in the dorsal and lumbar regions, although it is used only in abdominal operations. The idea of paravertebral conduction anesthesia originated with Sellheim, who attempted to block the eighth to twelfth intercostal nerves, as well as the iliohypogastric and ilioinguinal nerves at their emergence from the spinal column for abdominal operations, and gave explicit directions for introducing and passing the needle. According to his suggestion, the needle is inserted laterally 2 to 3 cm. from the median line until the vertebral arch is touched. It is then passed laterally over the border of the vertebral arch between two transverse processes, for 1 to 2 cm. more; on the posterior surface of the vertebral arch it encounters the nerves emerging from the spinal

foramen. While Sellheim's experiments were not altogether a failure, they were nevertheless practically impossible on account of the inefficient means of anesthesia then in use. He attempted intercostal anesthesia in the same manner, but at that time nothing was known about the relations of the sympathetic nerve and the rami communicantes to pain sense in the abdomen. That was first pointed out by Kappis.

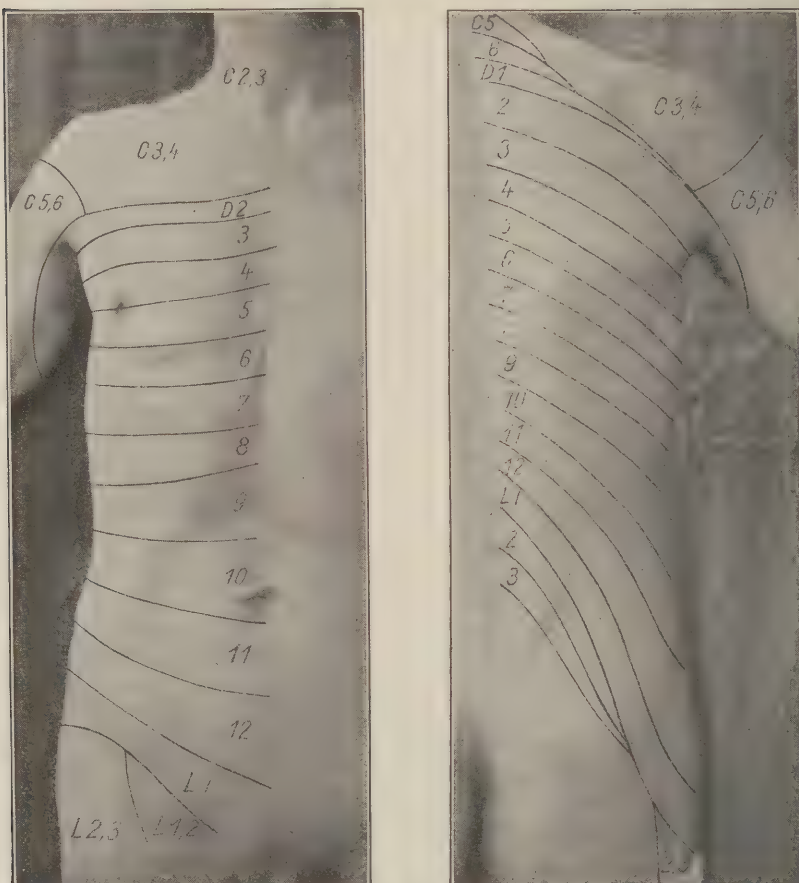


FIG. 123.—Segmental innervation of the breast, back and abdominal wall.

Laewen was more successful in his efforts. He called the method "paravertebral conduction anesthesia." In 1911 he reported having performed operations for inguinal hernia and nephrotomy (see Chapter XV) after blocking the lower dorsal and lumbar nerves. The experiments of Kappis and Finisterer showed that by paravertebral blocking of the intercostal and lumbar nerves in sufficient number not only the abdominal

wall but the abdominal cavity can be made anesthetic and that at the same time complete relaxation of the abdominal wall takes place as a result of motor paralysis. Lately paravertebral anesthesia has found

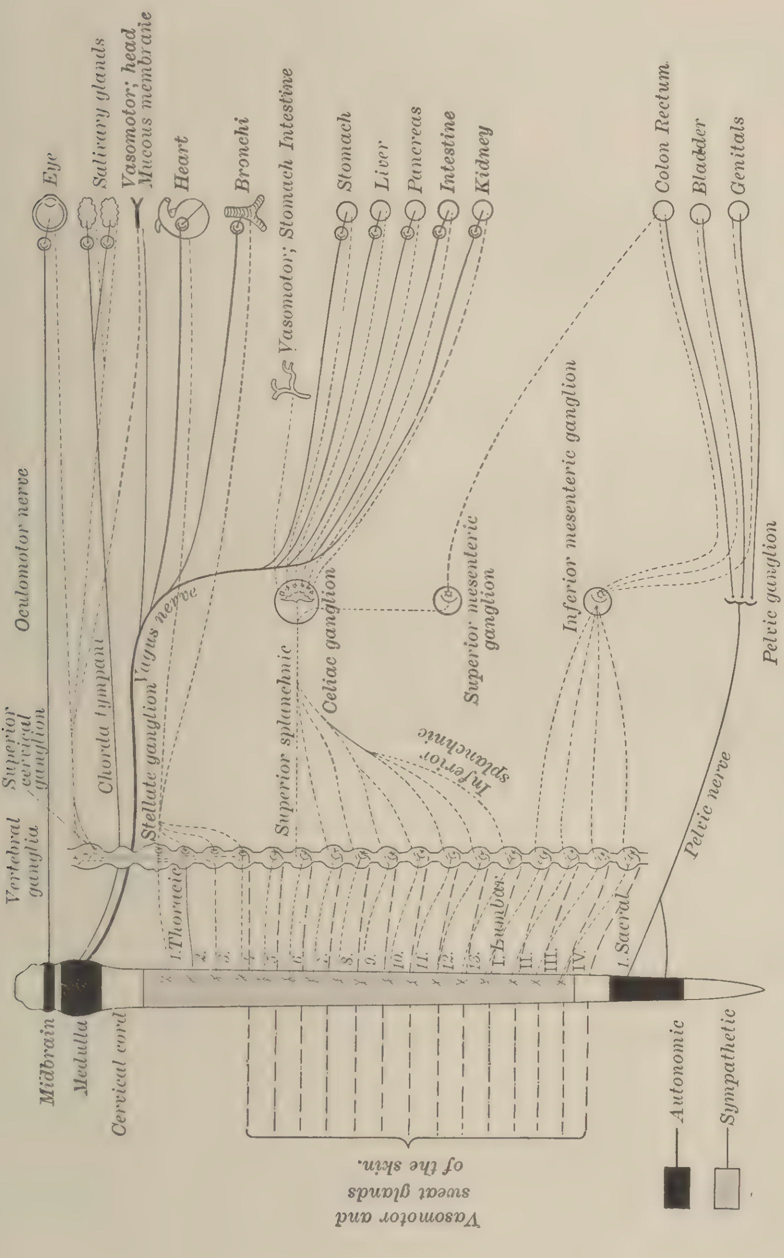


FIG. 124.—Schema of the vegetative (sympathetic) nervous system.

extensive use in abdominal operations (Holzwarth and Adam, Schmidt, Reinhard), and Siegel, based on his experience in 1000 cases, designates it as the normal method of producing anesthesia in all abdominal operations and in connection with parasacral anesthesia (see Chapter XV).

In all gynecological-abdominal sections and vaginal-abdominal sections the failures are said to be less frequent by this method than by lumbar and particularly sacral anesthesia. In paravertebral anesthesia not only the intercostal nerves but also the rami communicantes and the sympathetic nerves are blocked. To accomplish this the point of the needle must be brought somewhat nearer the vertebral canal. The best guide to the introduction of the needle in the dorsal region is the lower border of the ribs and not the transverse processes of the vertebræ as preferred by some authors. The author agrees with Siegel that it is never necessary nor practical nor even always possible to find each individual nerve with the point of the needle but that the blocking of the nerves is more certainly accomplished by thoroughly infiltrating the region in which they lie with 0.5 per cent novocaine-suprarenin solution.

The technic differs in the following manner from that described for intercostal injections. After a narrow strip of skin, about 5 cm. lateral of the spinous processes, has been made anesthetic by subcutaneous infiltration and the lower border of a rib has been located with the needle, the needle is withdrawn slightly and directed medial at an angle of about 120 degrees and introduced in this direction about 2 cm. The point of the needle should lie at about the angle of the rib along its lower border between the rib and the transverse processes. At times the needle will strike against the transverse process. It should then be raised up slightly more perpendicularly, so that it may pass a little in front of the process. While the needle is being introduced the injection should be begun in order that the pleura may be pushed away from it. From 15 to 20 cc of solution should be injected. When the injection has been made along several neighboring ribs one has an almost continuous subpleural infiltration near the vertebral canal and the fluid will often escape from the needle if allowed to remain in while the adjoining rib is being injected.

For reasons already given it is best to begin the injection at the twelfth rib. Leaving the needle in place, one proceeds to the upper lumbar nerve. The subcutaneous injection strip is extended downward. A needle 8 to 10 cm. in length is passed down to the transverse process of the first lumbar vertebra. Passing beneath its lower border it is inserted mediad and caudad to a depth of at least 2 cm. more and 20 cc of a 0.5 per cent of a novocaine-suprarenin solution injected. The same procedure is followed in injecting the second and third nerves. The fourth and fifth lumbar nerves are not to be reached in this manner but they are not concerned in the sensibility of the abdomen. The eleventh dorsal nerve is then injected followed by the tenth, etc., as a rule up as high as the fifth. The injection of each one is carried out in the same manner as for the twelfth. Preparation of the patient with scopolamine is indispensable.

The abdominal organs receive their pain-conducting nerve fibers

according to animal experiment by Kappis from the spinal segments as follows:

Stomach, Upper small intestine, Liver, Spleen	D 6 and D 7
Lower small intestine	D 8 to upper lumbar segments
Colon	lumbar segments
Kidney	D 8 to D 12

Practically this is of little significance since the lower and higher innervated regions lie in much confusion in the abdomen. In order to render the greater part of the abdominal cavity anesthetic, it is necessary to block a considerable number of segments. Kappis concludes on embryological grounds that the intestine in its entire length has a bilateral innervation. Therefore, as a rule, in operations on one side of the abdomen, it is necessary to block both sides. The parietal peritoneum and the organs of the pelvis are innervated by the sacral plexus, the latter also through mediation of the sympathetic nervous system. In operations within the pelvis Reinhard and Siegel combine paravertebral with parasacral anesthesia.

Siegel gives the following table showing the various points of injection and the amount of a solution necessary to inject for the several abdominal operations.

	Bilateral Injection		0.5 per cent novocain suprarenin solution.
Surgical abdominal I incision	Paravertebral	D5 to D12 L1 to L3	330 ccm., 22 points of injection.
Gynecological abdominal incision	Paravertebral	D7 to D12 L1 to L3	400 ccm., 20 points of injection.
	Parasacral	S1 to S5	
	Paravertebral	D11 to D12 L1 to L3	400 ccm., 10 points of injection.
Vaginal, uterus and adnexa operations	Parasacral	S1 to S5	
	Unilateral Injection		
Appendectomy	Paravertebral	D5 to D12 L1 to L3	220 ccm., 11 points of injection.
Nephrectomy	Paravertebral	D4 to D12 L1 to L3	240 ccm., 12 points of injection.

Concerning the above the following observations may be made: Bilateral paravertebral blocking to the above mentioned extent suspends completely abdominal sensation and tension of the abdominal wall. Unilateral blocking, as for appendectomy, does not ensure, according to the experience of the author and of Kappis, suspension of abdominal sensation. The abdominal wall and parietal peritoneum alone are anesthetized, and that can be produced in a much simpler way. In unilateral blocking the kidney pedicle as a rule is sensitive. (Kappis). On the other hand Jurasz by right-sided paravertebral blocking of the D6 to L1 has been able to perform two complicated gall-bladder operations without pain

and recommends this procedure in cases in which contraindications exist to general narcosis.

Unfortunately there are certain disadvantages connected with paravertebral anesthesia in abdominal operations which have not yet been overcome. In the first place, the technic is not easy, at least for beginners. That, however, pertains to every technic. Under all circumstances one must avoid placing the end of the needle too near the intravertebral foramina. Wilms, Franke and Kappis have seen severe collapse follow paravertebral injection which they ascribe to the injection of the solution into the spinal canal. Moreover, Muroya has shown experimentally that novocaine injected paravertebrally is more toxic than when injected subcutaneously. However, if one follows closely the technic as described by the different authors, one will scarcely puncture the intervertebral foramen, particularly if one makes the introduction of the needle through the skin at the proper distance from the midline, as mentioned by Siegel. Jurasz has rightly said that the secondary effects need not always be attributed to the injection of the solution into the spinal canal, but often more likely to the use of too large a dose of novocaine. This criticism must be considered justified when it is learned that Kappis in paravertebral anesthesia has used as much as 3.3 gm. of novocaine of a 1.5 per cent solution, and Siegel 3.8 gm. of a 0.5 per cent solution. Such doses are certainly not well borne by all individuals, although the use of the weaker 0.5 per cent solution by Siegel is an improvement and considerably reduces the danger of secondary effects.

Since in a majority of abdominal operations bilateral injections in from 20 to 22 places must be made, paravertebral anesthesia must try the patience of both surgeon and patient. Owing to the large number of nerves to be blocked, failures cannot be prevented. In spite of the strong recommendation of Reinhard and Siegel, the author is of the opinion that the question of local anesthesia in abdominal operations by means of paravertebral injections has not been satisfactorily solved. The author agrees with Jurasz that the method should be reserved for certain cases, in which narcosis must be avoided and in which it is probable that the operation can be performed under unilateral blocking. Splanchnic anesthesia which makes paravertebral anesthesia unnecesasay in many abdominal operations is described in the following chapter.

OPERATIONS ON THE SPINAL COLUMN.

The use of local anesthesia is of special value in performing laminectomies, owing to the field of operation being rendered bloodless (Braun).

Just as operations in the region of the trigeminus assume a totally different character after injections of novocaine-suprarenin solution, so do operations on the spinal column. They can be performed almost without any bleeding, and the patient leaves the operating table in a decidedly better condition than we have formerly been in the habit of seeing. The unpleasant necessity of operating in two stages is not experienced in

either laminectomy or Foerster's operation. A detailed discussion of these operations is needless at this time. The Foerster operation was performed upon one side of a corpulent elderly lady with spastic spinal paralysis without noticeably affecting her general condition.

In laminectomies, in addition to local anesthesia, general anesthesia should always be used in certain phases of the operation, as the Foerster operation is hardly possible without it, if the operator wishes to avoid

Fig. 125.—Injection for laminectomy.

intradural injections. Simple laminectomy for the relief of pressure on the spinal cord can, according to Heidenhain and Krause, be frequently performed without general anesthesia.

In performing laminectomy, the best method is usually as follows (Fig. 125): A number of points of entrance are marked surrounding the field of operation. This should be sufficiently large so that one is no way hampered. The next step is to make a bilateral injection of a 0.5 per cent novocaine-suprarenin solution, between the ribs and transverse

processes respectively. Then the erector spinæ muscle is thoroughly infiltrated with a 0.5 per cent novocaine-suprarenin solution, and finally the whole field of operation is subcutaneously circuminjected with the same solution. In exposing the spinal column there is no pain in any case. If the patient complains during the removal of the bony parts, it is advisable to give a little ether. There is practically no bleeding.

OPERATIONS ON THE THORAX.

Puncture of the Pleura.—Anesthesia for pleural puncture is produced (according to Fig. 35 (page 195) with a very fine needle. For this injection 0.5 novocaine-suprarenin solution is sufficient. It is much easier on the patient if the anesthesia instead of being limited to freezing the skin extends over the entire tract to the pleura before inserting a thick needle or trocar.

Resection of Ribs and Thoracotomy for Empyema.—Fig. 126 represents three successive ribs; from the middle one that part is to be resected which is marked in black. Wheals marking the four points for injection are made over the two neighboring intercostal spaces, and at these points the needle is inserted perpendicularly to the surface of the skin, and 10 cc of 0.5 per cent novocaine-suprarenin solution is injected between and into the intercostal muscles. In making this injection, the point of the needle should always seek the next rib above in order to find the necessary depth, and then pass along its lower border into the intercostal space. The muscle covering the rib and the subcutaneous connective tissue are then infiltrated with 30 to 40 cc of a 0.5 per cent novocaine-suprarenin solution in the direction of the arrows. This operation is always performed under local anesthesia, even in children under four years of age, the patient being placed in a sitting posture. In children it is usually necessary to use psychic influence, to induce them to permit the injection to be made, after which the rest is easy. One of our little patients ate a sandwich during the operation. Fig. 127 represents a patient during the resection of a rib.

Resection of Several Ribs or Rib Cartilages and Parts of the Thoracic Wall.—If the described intercostal injections are made not only in one, but in two, three or four intercostal spaces, in front of and behind the field of operation, and if the soft parts covering the thorax are circuminjected with a 0.5 novocaine-suprarenin solution (Fig. 128), larger areas of the thoracic wall can be made insensible; large pieces of rib can be removed and parts of the thoracic wall can be resected.

Resection of Cartilage of Second to the Fifth Ribs in the Fixed Dilated Thorax.—Over the second to fifth intercostal spaces mark two rows, each having five points of injection (Fig. 129). Of these the lateral row lies beyond the border of the cartilage of the ribs; the median row lies close to the sternum. From each of these points in the usual manner, 10 cc of 0.5 per cent novocaine-suprarenin solution into the intercostal spaces; the field of operation is circuminjected in the direction of the dotted line

with 50 cc of a 0.5 per cent novocaine-suprarenin solution. The operation is painless and bloodless. Fig. 130 shows one of the patients during the operation. The rib cartilage is removed together with the intercostal

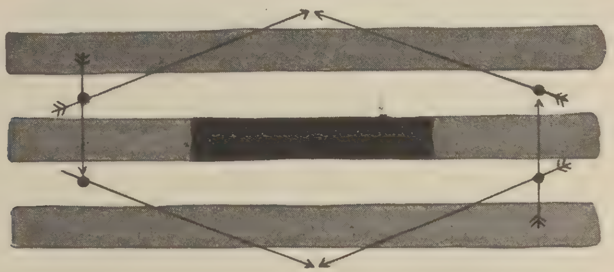


FIG. 126.—Injection for resection of the ribs for empyema. (Diagrammatic.)

muscles, according to Krueger. The base of the wound is formed by the pleura. On account of the deep respiratory movements the photogram is not clear; at any rate it will show what can be done with local anesthesia.

FIG. 127.—Patient during resection of ribs for empyema. Skin is painted with iodine.

The same method of anesthesia is suitable in operations on the heart and pericardium. The author had only one opportunity to use it in pericardiotomy, and that for purulent pericarditis in a child.

He has for years operated for subphrenic abscesses which were to be

FIG. 128.—Anesthesia of several ribs by intercostal injections and circuminjection.

FIG. 129.—Injection for resection of second and fifth rib cartilages.

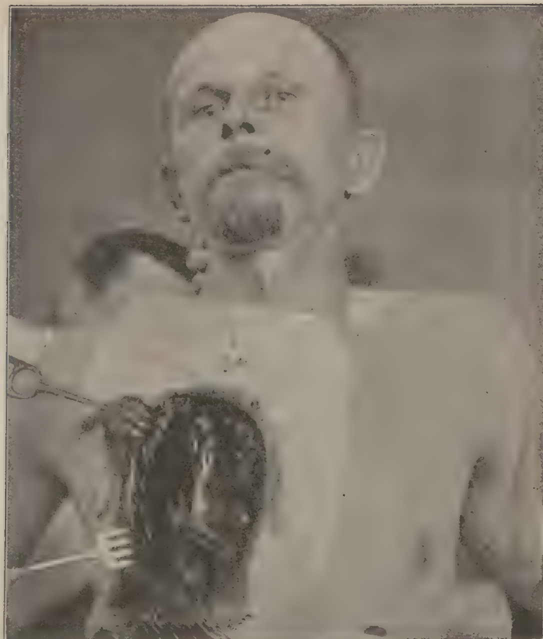


FIG. 130.—Patient after resection of second and fifth rib cartilages with the intercostal muscles for emphysema, under local anesthesia. The field of operation is covered with oiled silk. The base of the wound is formed by the pleura.

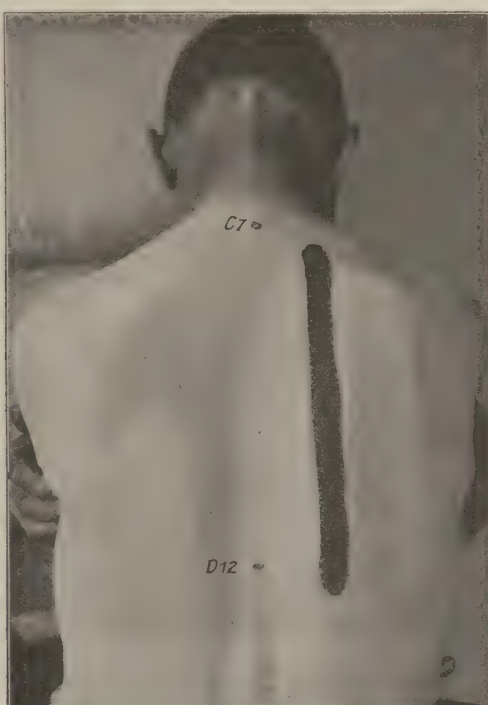


FIG. 131.—Subcutaneous line of injection for blocking the first to twelfth intercostal nerves.

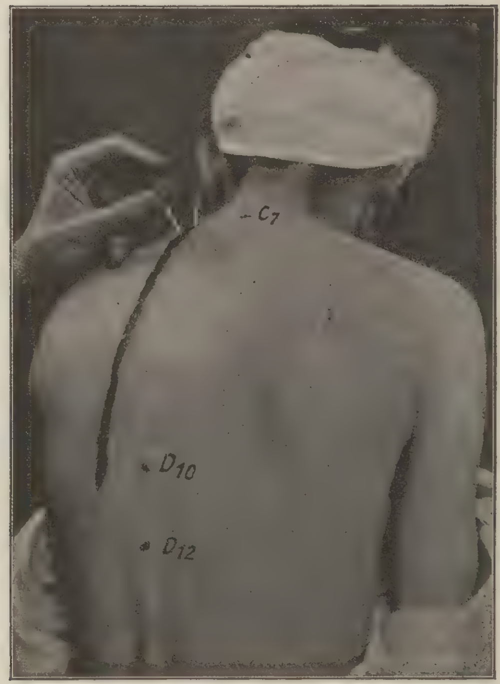


FIG. 132.—Blocking of first to tenth intercostal nerves for breast amputation. The upper needle is in the first intercostal space, the lower needle locates the second rib.

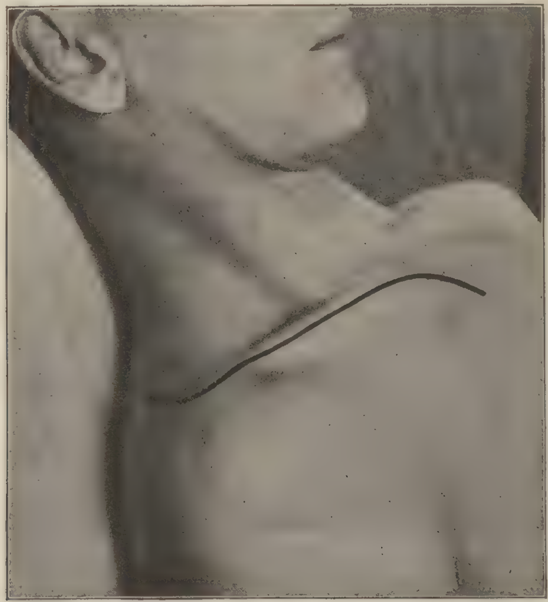


FIG. 133.—Subcutaneous line of injection for blocking the supraclavicular nerves.

opened through the thorax, a few lung abscesses, a few cases of circumscribed rib tuberculosis, and thoracoplasty for small localized empyemas. The latter were not always satisfactory, for in old empyemas, as Schumacher has pointed out, the ribs are so crowded together and overlap one another to such an extent that the intercostal injections in the neighborhood of the field of operations are fraught with numerous difficulties. These difficulties do not arise when the injections are made close to the spinal column.

Operations on the Sternum.—The injection is made as far as it is necessary on both sides into the intercostal spaces, close to the sternum, with 10 cc of 0.5 per cent novocaine-suprarenin solution; the field of operation is then subcutaneously circuminjected with a 0.5 per cent solution.

OPERATIONS ON THE BREAST.

It is a very easy matter to remove from the breast a well-defined benign tumor, whether large or small, under local anesthesia. Two or four points of entrance are marked in the neighborhood of the field of operation, the tumor is lifted up from the underlying structure (Fig. 134)

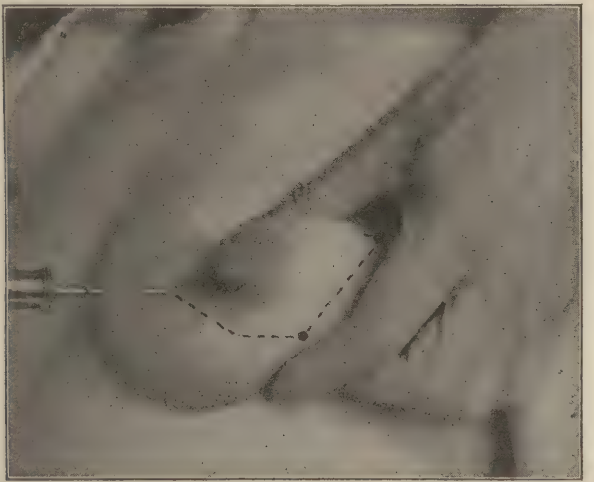


Fig. 134.—Circuminjection of a fibroma of the breast.

with the left hand and a pyramidal circuminjection of 50 to 75 cc of a 0.5 per cent novocaine-suprarenin solution is made. In lean women with small breasts the injection beneath and around the gland from several points will sometimes be sufficient for ablation of the breast. Inflammatory and especially phlegmonous conditions are better operated under ethyl chloride or ether anesthesia. [In removing benign tumors of the breast areas of chronic cystic mastitis, etc., the line of incision (which should

always be made in the natural fold between the breast and the chest wall to the outer or lower side not over the breast itself) should be anesthetized by subcutaneous injection of a 0.5 per cent novocaine-adrenalin solution. A long needle is then introduced into the loose submammary connective-tissue space and this space infiltrated with the same solution. With the flat of the hand the breast is gently pressed against the chest wall to cause a uniform distribution of the injected solution. By incising along the anesthetized line into the submammary space the breast may be turned

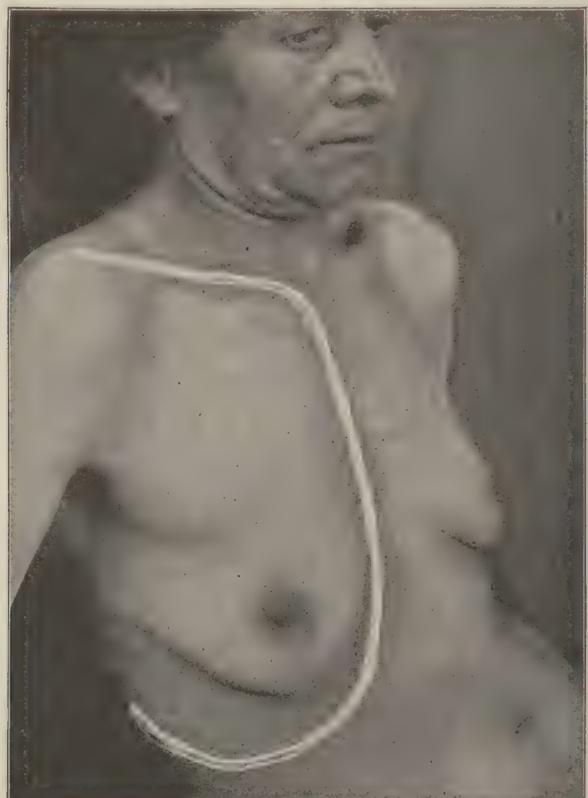


FIG. 135.—Subcutaneous injection for amputation of the breast.

up and any portion of it, including benign tumors, removed without pain. By subcutaneously injecting the proposed line of incision the entire breast, including the overlying skin, may be painlessly removed by this method. In a case of malignancy which, of course, requires a more radical operation, a more extensive blocking of the entire region and axilla is necessary.—ED.]

Excision of a Cancerous Breast.—Occasional operations of this kind were formerly done under local anesthesia by Schleich, more recently by Chaput, Hirschel, Hohmeier and Eberle. Hirschel operated on 3 cases

in lean women. They were not classical operations, as only small parts of the chest muscle were removed. Hohmeier also limited the use of local anesthesia to appropriate cases in lean women with small movable tumors.

Eberle has operated on 6 patients, some of them fat women. The most thorough injection was made beneath and around the mamma and the chest muscle, together with intercostal injections in the lateral and front wall of the thorax, with infiltration of the boundaries of the axilla and injections into the nerve bundles in the axilla. In this manner the author has for years attempted to carry out the classical breast amputations in lean patients; the anesthesia was satisfactory in most cases, but it is improbable that this method of local anesthesia can ever come into general use for amputations of the breast. Since 1912, the author has performed most breast amputations that have come to him, whether in fat or lean subjects, under local anesthesia without the help of narcosis, with satisfaction to himself and to the patients. The method however, requires too much detail to be used except in special cases presenting definite indications.

OPERATIONS IN THE AXILLA.

Superficial operations in the axilla are performed after injections under and around the field of operation. As soon as the operator penetrates deeper into the axilla it becomes necessary to block the brachial plexus and the five upper intercostal nerves, in order to obtain a complete anesthesia of the axilla.

CHAPTER XIV.

ABDOMINAL OPERATIONS.

The possibility of performing abdominal operations under local anesthesia depends upon a number of circumstances, which must be considered in each individual case. It is a fact which was recognized after the introduction of the ether spray that anesthesia of the skin incision is occasionally all that is necessary for opening the abdomen, and for operations on the abdominal organs which have little or no sensation to pain. Local anesthesia with cocaine and its substitutes has made wonderful progress; for now, even in sensitive patients, a real exclusion of sensation is possible, permitting the abdominal layers to be incised from skin to peritoneum with ease and comparative safety.

If the operation is to be performed in or upon the abdominal wall, as is the case in most operations for hernia, or if a simple incision through the abdominal wall immediately exposes the organ to be operated upon, and if further manipulation in the abdominal cavity is not necessary, then local anesthesia will be sufficient. Incisions into the stomach and bowel, the liver and gall-bladder and other abdominal organs are not painful. The sensibility of these organs is the same whether in an inflammatory or non-inflammatory state. On the other hand, painful sensations, called "abdominal sensations" (page 36), are produced by any traction on the bowel, or any touch or tearing of the parietal peritoneum, if not anesthetized. Pains are also often felt in tying off the mesentery, but usually not in tying off the omentum. The intensity of these sensations differs in each individual. In some patients it is possible, after incising the abdominal wall, to perform any abdominal operation desired without a complaint. Usually, however, this is not the case. Usually any examination of the abdominal organs, the introduction of the hand into the abdominal cavity, the application and removal of compresses, the separation of adhesions, is so painful that further operation is not to be considered. Various efforts have been made to overcome these abdominal sensations.

In many operations, particularly in the lower abdomen, complete relaxation of the abdominal muscles is indispensable. For midline incisions the abdominal wall may be anesthetized by simply infiltrating the line of incision. The author does not carry this out from without inward, as recommended formerly by Reclus and Schleich, but in reverse direction from within outward. A wheal is placed at the end of the intended incision. Through this the loose subaponeurotic tissue is infiltrated freely with a 0.5 per cent novocaine-suprarenin solution, and then the subcutaneous cellular tissue. The injected fluid spreads quite freely

between the aponeurosis and the peritoneum, so that a sufficiently wide strip of peritoneum becomes anesthetized. Some abdominal operations can be performed under local anesthesia without the aid of narcosis by this simple method of infiltrating the line of incision. To these belong gastrostomy by the transrectal incision (Fig. 136). In injecting the abdominal wall from both ends of the incision, one must be careful that the needle passes through both sheaths of the rectus in order to reach the properitoneal tissue. That is not difficult, as the resistance of both aponeurosis may be felt as the point of the needle penetrates them. Tuberculous ascites, echinococcus of the liver, and liver abscess when accessible from the abdomen may be operated on by the same method. Infiltration

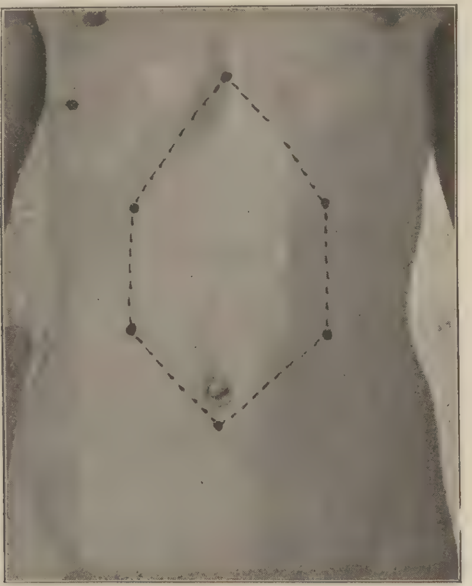


FIG. 136.—Injection for gastrostomy and the circuminjection of the upper abdominal region. (White.)

of the line of incision is usually sufficient for establishing an intestinal fistula, but in ileus the needle must be introduced very carefully in order not to puncture the greatly distended intestine firmly pressed against the abdominal wall. If, instead of infiltrating the line of incision, circuminjection be used, a considerably larger field of operation on the inner side of the abdominal wall will become anesthetized. Fig. 136 and 137 show this method for midline incisions above the umbilicus. The second is particularly simple. The circuminjection which must include all of the layers of the abdominal wall follows the border of the ribs above and the edge of the rectus muscle laterally where the nerves entering the field lie directly beneath the aponeurosis. Circuminjection is particularly to be preferred to infiltration of the line of incision when abdominal pads

20

must be placed within the open abdomen. In order that the placing and removal of the abdominal pad may be made painless, it is necessary that a much larger area of peritoneum be anesthetized than can be done by infiltrating the line of incision. Circuminjection is the method of choice for the closure of intestinal fistulæ and artificial ani. In these cases it is very easy to reach the properitoneal space as the needle can be introduced under guidance of the finger placed within the bowel.

The entire anterior abdominal wall may be rendered anesthetic by a simplified, unilateral or bilateral blocking of the intercostal or lumbar nerves. The technic differs from that described on page 285 for operation on the thorax in that the blocking need not be done so far posteriorly, but more laterally where the ribs are superficial and more easily palpable. The blocking is performed as follows (Fig. 138): The patient lies on the back with the arm extended upward. The point of the twelfth rib is

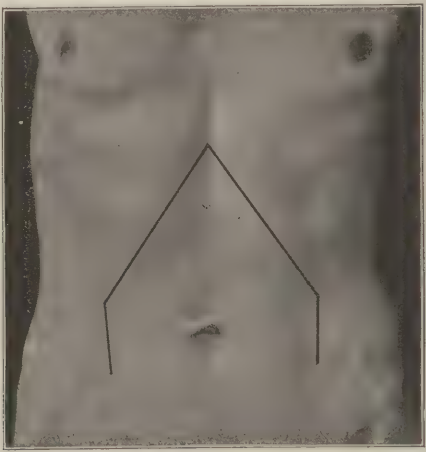


FIG. 137.—Anesthesia of the abdominal wall for incisions above the umbilicus.

located and a point directly in front of it on the eleventh rib is marked as one point of entrance. The next point of entrance is marked directly opposite the first point at the crest of the ilium. The tissues intervening between these two points, which contain the eleventh and twelfth intercostal nerves and the iliohypogastric and ilioinguinal nerve are thoroughly infiltrated with a 0.5 per cent novocaine-suprarenin solution, as shown in Fig. 36, page 196. The needle is then introduced in the tenth intercostal space in the axillary line and 10 cc of the solution injected along the lower border of the rib. This is repeated for the ninth, etc., ribs as may be necessary. This can be done easily and quickly as the ribs are superficial in this region. In operations below the navel the injections may be made only as high as the eighth rib. The anesthesia of the abdominal wall will then extend from Poupart's ligament to a little above the navel. In incisions above the navel infiltration of the lumbar region

below the eleventh and twelfth ribs may be omitted, and the injection of the intercostal spaces extended upward as far as the fifth or sixth rib.

Franz has employed this method unilaterally and bilaterally with good results in the treatment of gunshot wounds of the abdomen in the field. The wounded were prepared with morphine and scopolamine. In 41 cases no failures were noted. In 11 instances the operations were completed without narcosis; in the remaining cases short light ether narcosis

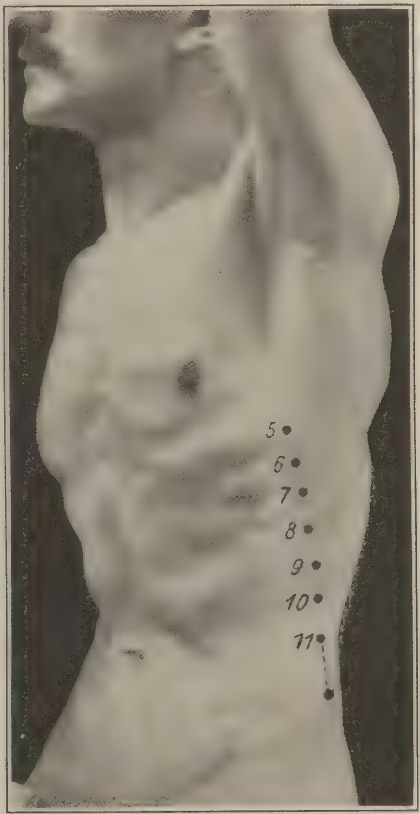


Fig. 138.—Blocking of the abdominal wall nerves.

was necessary. For lateral incisions and one-sided operations in individuals not too fat, this is one of the best methods of producing anesthesia of the abdominal wall. It is technically simple and on account of the small amount of solution used without danger. It possesses also the advantage of muscular relaxation.

The simplest way of anesthetizing the abdominal wall in the ileocecal region is a combination of conduction anesthesia and circuminjection. Two points of entrance are marked, one at the crest of the ilium and the

other directly opposite on the costal arch. The thick muscular layers lying between these points which contain the eleventh and twelfth intercostal nerves and the branches of the upper lumbar nerves are freely infiltrated with the 0.5 per cent novocaine-suprarenin solution. Finally the entire field of operation is infiltrated subfascially and subcutaneously from two additional points (Fig. 139).

Different methods have been suggested to overcome abdominal sensation. In certain abdominal operations this may be accomplished by the method first proposed by Schleich and later used by Mikulicz and more recently warmly recommended by Bakes, Laewen, Finsterer and others. The field of operation is anesthetized in the usual way and then during certain parts of the operation in which abdominal sensation is to be

Fig. 139.—Appendectomy.

expected light ether anesthesia is employed. This method will be more effective if the patient has been prepared with morphine and scopolamine. If the patient is well under morphine and scopolamine before beginning the operation, one is frequently able to dispense entirely with narcosis, since during scopolamine "twilight sleep" the abdominal sensation is very materially diminished. The author has employed this method regularly for some years in operations on the stomach. A gastro-enterostomy is carried out about as follows:

The patient is prepared with narcotics. The circuminjection of the upper abdominal wall is then made in the manner described. During the opening of the abdomen light ether narcosis is induced which permits the exploration of the abdominal cavity and a determination of the findings and the placing of abdominal pads, after which the patient is allowed to

wake up and requires no further narcosis. Light etherization seems to be the best form of narcosis to use as an aid to local anesthesia in abdominal operations. From the author's experience he can warmly recommend ethyl chloride for this purpose as recommended by Kulenkampff. Ethyl chloride is sprayed from the customary glass tube on a folded compress which covers the mouth and nose of the patient. After a few inhalations the desired degree of insensibility to pain results and on removing the compress the patient wakes up at once. This form of narcosis is particularly suitable as an aid to local anesthesia on account of the rapidity with which insensibility sets in and the absence of any irritating effects of the drug on the respiratory organs and the brain. The same procedure is followed in pylorectomy. As a rule, a second light narcosis is necessary when tying off the lesser omentum and at times a third to permit the removal of the abdominal pads. [The Editor has found the use of nitrous oxide and oxygen gas the most satisfactory method of producing short general anesthesia when the same seems desirable during abdominal operations done under local anesthesia. The patient passes under and out of the gas so quickly and no after-effects are noted.—Ed.]

There can be no question but that the patient who has been handled in this manner comes from the operating table in a much better condition than one who has undergone a long-continued complete narcosis. Nothing perhaps illustrates so forcefully the harmful effects of prolonged narcosis as this common observation. Greatly reduced patients with pyloric stenosis withstand a pylorectomy without any or only a passing effect on their general condition and without the necessity of using infusion of salt solution and other restoratives. This mixed method of anesthesia proved its great value to the author and Laewen in the treatment of bullet wounds of the abdomen in the field.

Likewise this method may be used in some cases of simple ovariotomy with slight effect on the general condition of the patient. As a rule, however, gynecological laparotomies are not well adapted to this method because they require complete relaxation of the abdominal muscles and because the operative procedures are not like stomach and intestinal operations which for the most part can be performed outside of the cavity and on organs which are not sensitive. The same applies to operations on the gall-bladder.

Hesse and Spenglein have reported on the use of local anesthesia in appendicitis. Hesse considers suitable for local anesthesia: (1) All cases operated on during the interval; (2) chronic cases running a mild course; (3) severe and light acute cases in the early stages of the first or similar attacks. He considers the method contraindicated in: (1) Practically all abscesses; (2) in cases in which complicated pathological-anatomical relations are to be expected. [Local anesthesia may be used very satisfactorily in practically all operations on the appendix whether acute or interval cases. Should it be necessary on account of adhesions to invade unblocked areas, the use of a little nitrous oxide and oxygen gas for a moment or two, as mentioned above, is all that is necessary.—Ed.]

If circuminjection has been performed, in the manner described above, any desired incision may be made through the abdominal wall, the wound retracted and the cavity packed off without pain. Abdominal sensation usually localized in the region of the stomach may be felt on separating the adhesions or drawing on the cecum or ligating the mesenteriolum. Hesse's advice to infiltrate the mesenteriolum before ligating it only partially prevents this sensation. It is better, therefore, to combat this sensation with morphine-scopolamine as Stenglein recommends, and, if necessary, ethyl chloride anesthesia during the search for an isolation of the appendix. The advantage of the combined method of anesthesia in operations for appendicitis are not so striking as they are in operations on the stomach, and since the indications and contraindications of Hesse can often be determined only during the operation, the author confesses that after many past experiences he has returned to the opinion that, as a rule, operations on the appendix should be done under narcosis and only exceptionally under local anesthesia.

Concerning lung complications after abdominal operations, too much weight has been given to the method of anesthesia. These complications are not so dependent on narcosis as has been generally accepted. What local anesthesia can practically entirely prevent in contrast with narcosis are the aspiration complications. A great majority of lung complications after abdominal operations are retention complications in the sense of Czerny. Local anesthesia has as little influence on them as it has on complications due to emboli. These lung complications, therefore, cannot be prevented by local anesthesia.

[While it is true that the majority of lung complications are due to retention, it must be admitted that the irritating effects of the ether greatly increases the amount of tracheal and bronchial mucus and thereby adds to the difficulty of keeping the respiratory tract clear. In this respect local anesthesia has a decided advantage over ether anesthesia. —Ed.]

Observations with mixed anesthesia in major abdominal operations justify the attempts which have been made to eliminate abdominal sensation by local means and thus to dispense entirely with narcosis. One of the methods proposed—paravertebral conduction anesthesia—has been already mentioned and explained, but it has not satisfactorily solved the problem of local anesthesia in abdominal operations. Schmiedt has called attention to a simplification of this method for operations in the upper abdomen. If the abdominal wall itself be anesthetized by circuminjection, it will be necessary to block paravertebrally on both sides only the sixth, seventh and eighth intercostal nerves while in paravertebral anesthesia alone it is necessary to block twenty-two nerves in order to secure at the same time anesthesia of the abdominal wall and cavity. Another method of eliminating abdominal sensation from a definite large section of the abdominal cavity by simple and certain procedure without the help of narcotics is based on the fact that the nerves which supply pain sense to the organs of the upper abdomen (liver, gall-bladder, stomach,

duodenum, and upper small intestine) return to the spinal cord exclusively by way of both splanchnic nerves (Neumann, Kappis, p. 285). The nervus splanchnicus major passes through the diaphragm with the vena azygos between the crus mediale and the crus intermedium diaphragmatis on the anterior surface of the twelfth dorsal vertebra and the nervus splanchnicus minor takes either the same course or passes through the diaphragm a little more to one side. After entering the abdomen both nerves lie near the aorta in the loose connective tissue beneath the attachment of the omentum minus to the posterior abdominal wall and at the level of the origin of the arteria cœliaca pass into the plexus cœliacus. This region is accessible to the needle both from behind and in front.

Kappis, who proposed the posterior route, described the introduction of the needle as follows: With the patient lying on the side a 12 cm. needle is introduced at a point 7 cm. laterad of the midline at the lower border of the twelfth rib. The needle is passed forward and inward in the direction of the body of the vertebra. As soon as the needle comes in contact with the body of the vertebra, one feels one's way along until the needle passes the vertebra. It is then introduced 1 cm. farther when the point of the needle will be found to lie in or on the lateral attachments of the diaphragm to the vertebral column, where also lie the splanchnic nerves. The same procedure is carried out on the opposite side. Kappis injects on either side from 20 to 40 cc of a 1 per cent novocaine-suprarenin solution, then carries the needle a little farther downward on the lateral surface of the lumbar vertebra and injects 15 to 20 cc more of the solution. The abdominal wall is anesthetized by local injections. Kappis has performed more than 200 operations, mostly on the stomach and gall-bladder, by this method and says that with increasing experience failures are rare. As secondary effects Kappis has seen frequent pallor, rapid pulse, palpitation of the heart, and lowering of the blood-pressure 15 to 20 mm. of mercury. Besides these light secondary effects others have seen frequent vomiting, severe collapse and delirium (Paul, Denk, Preiss, Haberer). Heller, Denk and Karo each report a death following the injection. The author believes that a final opinion on this interesting as well as therapeutically and diagnostically valuable procedure cannot yet be given. One must not forget that a procedure proved out by the discoverer may show disadvantages in the hands of others, which perhaps later may be overcome. At all events, here the limits of local anesthesia have been reached. Kappis, himself, does not believe that this procedure is a suitable substitute for narcosis in the extensive intra-abdominal operations.

Wendling's attempt to reach the vertebra from the front through the unopened abdominal wall should not be looked upon favorably on account of the danger of injuring the neighboring organs, however, when the abdomen is opened by a midline incision the anterior surface of the vertebra is easily and without danger accessible to the needle under guidance of the finger. It should be remembered that Dollinger, Finsterer, Hackenbruch and others have already recommended secondary infiltration of the lesser omentum in operations on the stomach.

For operations on the stomach, the author proceeds as follows: The abdomen is opened in the midline under careful circuminjection (simple infiltration of the line of incision is not sufficient) or intercostal conduction anesthesia. The left lobe of the liver is carefully drawn upward with a flat retractor (Fig. 140). The anterior surface of the first lumbar vertebra, which lies at about the level of the xiphoid cartilage, is now searched for with the index finger of the left hand. On pushing the pulsating aorta gently to the left, the tip of the finger comes in contact with the middle

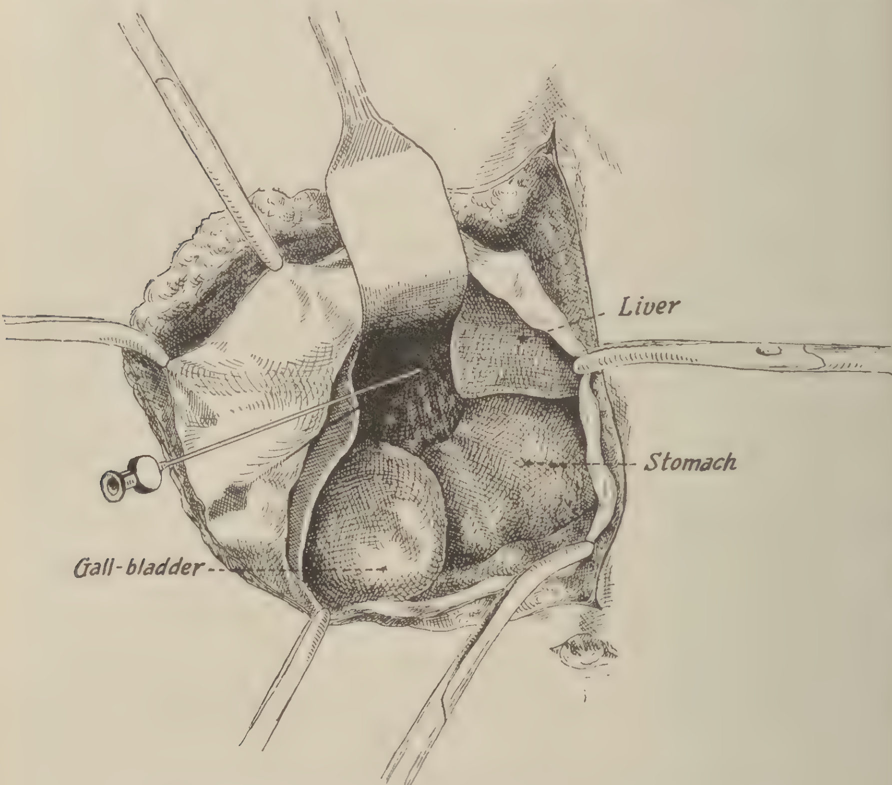


Fig. 140.—Needle introduced to anterior surface of first lumbar vertebra.

of the anterior surface of the vertebra separated from it only by the attachment of the crura of the diaphragm, a thin layer of connective tissue and the posterior layer of the peritoneum. A 12 cm. needle is now passed along the finger and pushed down to the bone. It strikes the bone almost immediately after entering the soft parts. Should this not be the case, the needle has gone astray. Bloodvessels cannot be injured in this way; the vena cava particularly lies farther to the right, however; the same caution should be observed here as in all other portions of the body to change the location of the needle should blood escape from it. Should

no blood escape from the needle, the left forefinger is withdrawn and without changing the location of the needle, 100 cc of a 0.5 per cent novocaine-suprarenin solution are injected. In this manner is produced an extensive infiltration of the soft parts covering the anterior and the lateral surfaces of the vertebra and containing the splanchnic nerves and the large ganglion, lying in front of the aorta. All of these manipulations should be made with the greatest gentleness and care. Particularly must be avoided all drawing on the lesser omentum, retraction of the abdominal walls and examination of the abdominal cavity until after the injection has been made.

In operations on the gall-bladder, the author uses the angular incision because it gives the freest approach to the deep gall tracts, and it gives rise to no further anxiety if the suture line is secured at the angle with lead plate sutures. It not infrequently happens that the transverse leg of the incision is unnecessary, as the operation can be performed through the midline incision alone. The method of producing anesthesia is as follows: (1) Intercostal blocking on the right side as described on page 306; (2) infiltration of the midline; (3) opening of the abdomen in the midline and injection of the tissues on the anterior surface of the vertebra in the manner described above; (4) extension of the incision transversely through the right rectus muscle. The effect of the injection down to the vertebral column is most striking. Anesthesia of the upper abdominal cavity makes its appearance almost immediately after the injection. While before the injection every pull on the stomach caused the patient to complain, almost immediately thereafter the stomach, transverse colon and the upper intestine can be packed off without any reaction on the part of the patient. The anesthesia extends to the small and large omentum, the hilus of the liver, the gall tracts, the pancreas and spleen, the mesentery of the small intestine, the transverse mesocolon, and the points of fixation of the upper part of the ascending and descending colons. How far downward on the colon it extends, the author has not been able to determine.

The author has made use of this method in 199 cases; 131 stomach operations, 57 gall-bladder operations and 11 times in other operations in the upper abdomen. The patients were prepared with scopolamine. There were but 16 failures. In fat persons and in the presence of adhesions it may not be possible at times to make the injection. The author has not observed any indication of after-effects. Vomiting after the operations has occurred very rarely. The blood-pressure was taken in the first 33 cases published by Buhre and showed no variations from that usually seen in every abdominal section. This method should be tested out by others, which, up to the present time, seems to have been done only occasionally.

OPERATIONS FOR HERNIA.

In hernia operations local anesthesia should be the method of choice, as it is suitable for all these operations. The abdominal sensations in these cases are very slight. Since the introduction of cocaine, local

anesthesia has been considered particularly suitable for hernia operations and has been used with more or less success. Every author who refers to this subject gives favorable reports, and as early as 1889, Reclus used local anesthesia in the majority of hernia operations. He designates the operation for strangulated hernia "the triumph of cocaine." He states that this is the anesthesia of choice, and in his judgment the use of general anesthesia is justifiable only under special conditions, such as herniæ of very large size, extensive adhesions, or the probability of complications.

Schleich's infiltration anesthesia was considered a step in advance for local anesthesia as the large doses of cocaine used by Reclus were no longer necessary; but it is an undeniable fact that this progress, at least in inguinal and femoral herniæ, was made at the risk of producing an uncertain anesthesia. The branches of the ilioinguinal, the spermatic, and the iliohypogastric nerves remain painful and capable of conduction, no matter how freely the tissues, in which they lie, are infiltrated with the Schleich solution. For this reason Cushing recommended that in operations for inguinal hernia the search for the nerve trunks which enter the field of operation should not be made until after the fascia of the external oblique muscle has been cut, and that they be blocked by an endoneural injection of a 1 per cent cocaine solution. Hackenbruch, starting out with an entirely different principle from Reclus and Schleich, injected the cocaine-eucaine solution in a fork-shaped or diamond-shaped area around the hernial ring.

All these methods have been superseded at the present time and are now of only historical value. They proved unreliable and difficult and their success depended too much upon the size of the hernia and other anatomical conditions. For this reason the use of local anesthesia for hernia remained in the hands of a few specialists. But there has been a great change since the advent of new anesthetizing solutions, with their simplified technic, and their greater reliability. In most of the surgical hospitals of Germany, herniæ are now operated upon under local anesthesia according to the method described by Nast-Kolb, von Lictenberg, and Braun.

Statistical reports have been made on this subject by Hesse from city hospital at Stettin, where 218 hernia operations were performed from January 1, 1909, to September 15, 1910, of which 170 were performed under local anesthesia, and 48 under general anesthesia. In the hospital at Zwickau there were 397 cases operated on for hernia from January 1, 1909, to October 1, 1911, and of these cases 345 were operated on under local and 52 under general anesthesia. It has already been mentioned on page 176 that childhood presents no contraindication to the use of local anesthesia in hernia operations; children are easily influenced, and if they can be induced to allow the injection, no further anesthesia will be required. During the operation it will, of course be necessary for some experienced person to entertain the child.

Operations for Umbilical Herniæ, Hernia of the Linea Alba, and Postoperative Hernia.—The abdominal wall is anesthetized on the same

principle as described for abdominal incisions above the umbilicus or ileocecal region. Four or more points of injection are marked surrounding the field of operation (Figs. 141 and 142) and proceeding from these the abdominal wall is circularly infiltrated down to the preperitoneal tissue

FIG. 141.—Anesthesia for umbilical hernia.

with a 0.5 per cent novocaine-suprarenin solution. This is exceedingly simple and easily done in a reducible hernia, in which case the left index finger is introduced into the ring, and, guided in this way, the injection is made. After a little experience this can be done just as well in irre-

ducible and strangulated hernia. In these cases, however, the operator must not expect to infiltrate the ring, for in irreducible hernia it is not accessible. He must rather aim to infiltrate a layer of the abdominal wall at some distance from the hernial swelling. This will cause the entire hernia to become insensitive. Large umbilical herniæ in fat persons require the greatest amount of anesthesia that we have used, 250 to 300 cc of a 0.5 per cent novocaine-suprarenin solution. Before undertaking a case of this kind it is necessary to know just how to guide the needle. In very fat persons it is advisable at first to infiltrate the skin and the subcutaneous connective tissue close to the hernial swelling; the aponeurosis is then exposed to the right and left of the hernial mass. The subaponeurotic injection can now be easily made as described; it is, however,

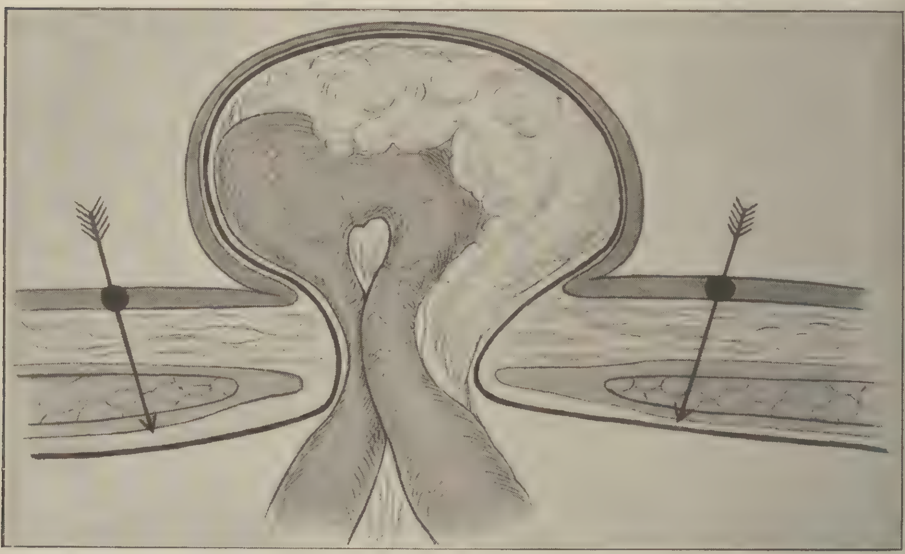


FIG. 142.—Cross-section of an umbilical hernia to demonstrate the extent of the deep injection.

necessary to wait until the peritoneum and hernial sac become insensitive. This method can be used in all cases of umbilical hernia.

Herniæ of the linea alba are anesthetized in the same way, the size of the circuminjected area depending upon the extent of the field of operation. Most postoperative herniæ can be easily operated upon under local anesthesia by circuminjection. Of late the author has been operating on all ruptures of the anterior abdominal wall under bilateral conduction anesthesia as described on page 306. This method is superior to local infiltration when the field of operation is large. Even the Menge-Graser operation for umbilical hernia and rectus diastasis may be readily done by this method. The use of scopolamine, as a rule, is unnecessary in these cases.

Operations for Inguinal Hernia.—The object of the injection technic is to block the nerve trunks supplying the field of operation before they reach it, and to circuminject the field of operation. Neither of these manipulations alone would be sufficient. Fig. 143 explains schematically the innervation of the inguinal and femoral region. The external spermatic nerve, which is a branch of the genitofemoral, joins the spermatic cord at the internal ring, and accompanying it emerges from the inguinal canal on the under surface of the cord to be distributed to the cremaster

Fig. 143.—Innervation of the inguinal and femoral region. 1, genitocrural nerve; 2, external spermatic nerve; 3, lumboinguinal nerve; 4, ilioinguinal nerve; 5, iliohypogastric nerve; 6, anterior cutaneous branches of the twelfth intercostal nerve.

muscle, tunica dartos, the skin of the scrotum or the labia majora, as well as the thigh in the region of the external ring.

The ilioinguinal nerve lies above the spine of the ilium, between the oblique abdominal muscles; passing under the fascia of the external oblique it leaves the inguinal canal on the anterior surface of the hernial sac or the spermatic cord. Branches of this nerve supply the skin of the thigh, the scrotum and pubic eminence. The iliohypogastric nerve runs almost parallel with and a little higher than the former, between the oblique abdominal muscles, and in the inguinal region under the fascia

of the external oblique muscle. It penetrates the anterior sheath of the rectus, in this manner reaching the subcutaneous connective tissues, innervating the skin of the inguinal region. The three nerves anastomose

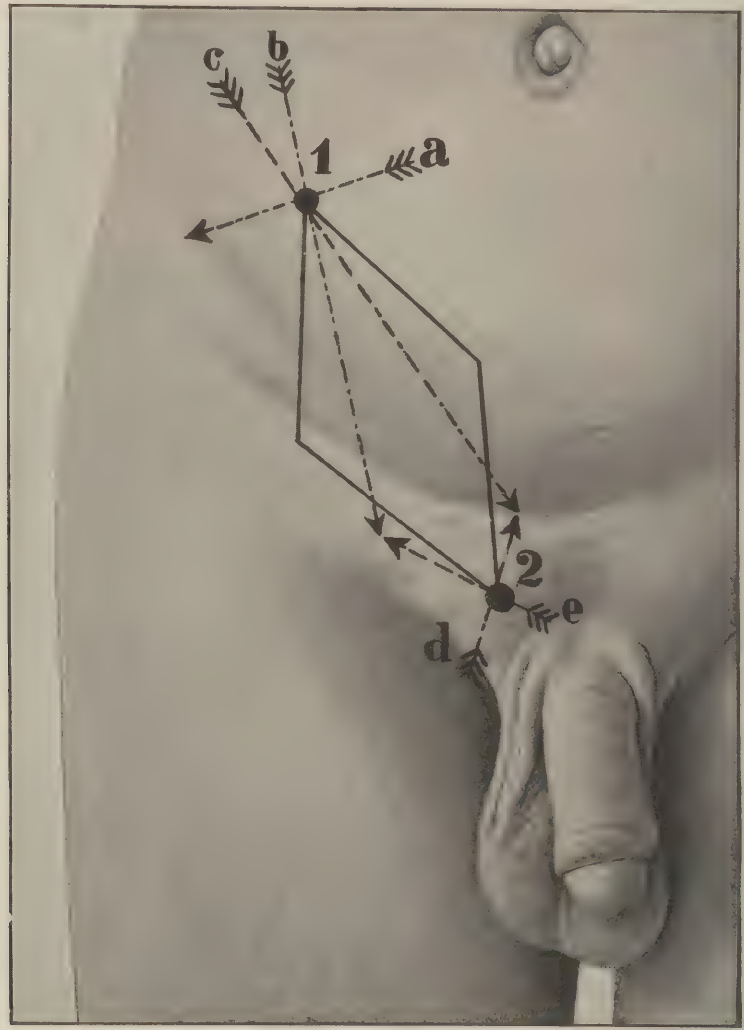


FIG. 144.—Injection for reducible inguinal hernia. The dotted lines indicate subaponeurotic injections, the continuous lines the subcutaneous injections.

with one another; one or two of them may be absent, in which case they can be replaced one by the other. Bodine declares that the iliohypogastric nerve is the most constant one and not infrequently sends a branch through the inguinal canal, thus replacing a branch of the ilioinguinal.

The ilioinguinal and the external spermatic can also replace one another. The lumboinguinal, which is more deeply seated, is scarcely taken into consideration in operations for inguinal hernia. Cushing has called attention to the fact that if the three nerves first mentioned are cocainized at their entrance into the inguinal canal, the greater part of the field of operation will become insensitive.

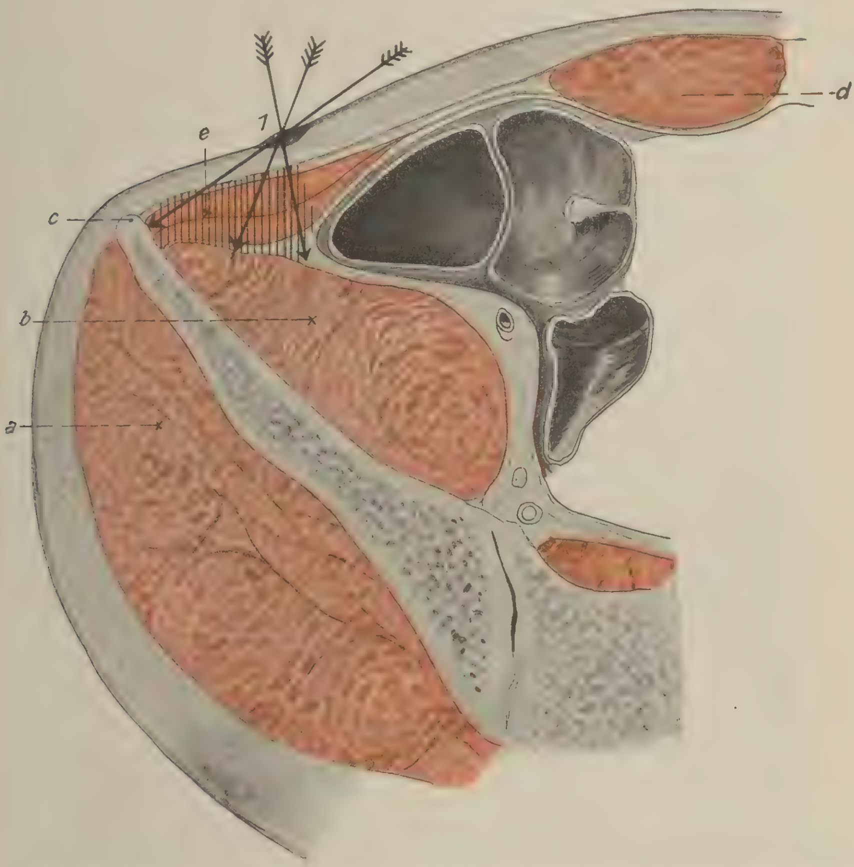


FIG. 145.—Cross-section of the abdomen at the level of the anterior-superior spine of the ilium. (Made from frozen section.) *a*, gluteus muscle; *b*, iliac muscle; *c*, spina ilei; *d*, rectus abdominus muscle; *e*, external and internal oblique and transversalis muscles. The location of the trunk or branches of the iliohypogastric and ilioinguinal nerves is shaded black. 1 is the point for injection.

Method Used in Reducible Inguinal Hernia.—Two points of entrance are marked (Fig. 144). Point 1 lies three finger-breadths internal to the anterior-superior spine of the ilium. Point 2 is exactly over the horizontal ramus of the pubes at the outer inguinal ring. From point 1 the muscular layer (arrow A) lying between the point of injection and the ilium is

infiltrated according to Fig. 36 (page 196). About 20 cc of a 0.5 per cent novocaine-suprarenin solution is injected in the following manner (Figs. 145 and 146): The long needle is first entered perpendicular to the surface of the skin, then through the aponeurosis of the external oblique muscle and through the muscular layers of the internal oblique and transverse muscles; it is then withdrawn and inserted twice again, each time in a more oblique direction toward the spine of the ilium, until the point of the needle strikes the iliac bone. The thick muscular layer situated in this region must be infiltrated. This injection blocks the ilioinguinal and the iliohypogastric nerves. From point 1 further injection of 10 to 20 cc of 0.5 per cent novocaine-suprarenin solution is made under the aponeurosis of the external oblique muscle in a fork-shaped manner

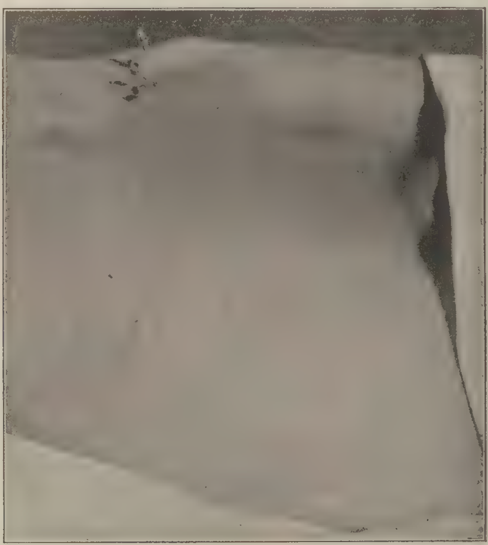


FIG. 146.—Guidance of the needle for injections near the iliac spine in inguinal and femoral herniæ.

toward a point lying in the median line, laterally from the inguinal ring (arrows *b* and *c*).

From point 2 a deep injection of 10 cc of the solution is made in a fan-shaped manner, and with each injection the needle will strike the pubic bone. From point 2 further injections of 10 cc are made in a fork-shaped manner under the aponeurosis in the inguinal canal along the spermatic cord (arrows *d* and *e*). The skin incision is finally circuminjected subcutaneously in the form of a rhombus, 75 to 100 cc of 0.5 per cent novocaine-suprarenin solution being necessary for the entire injection. In double hernia both sides are injected before the operation is begun.

Method of Operation in Irreducible or Strangulated Inguinal Herniæ.—The position of the points of injection, as well as the subcutaneous

and subaponeurotic or subfascial strip of injection is shown in Figs. 147 and 148. From point 1 the injections are made, as already described, toward the iliac spine, then follow the subaponeurotic injections toward points 2 and 3. These are followed by deep injections from points 2 and

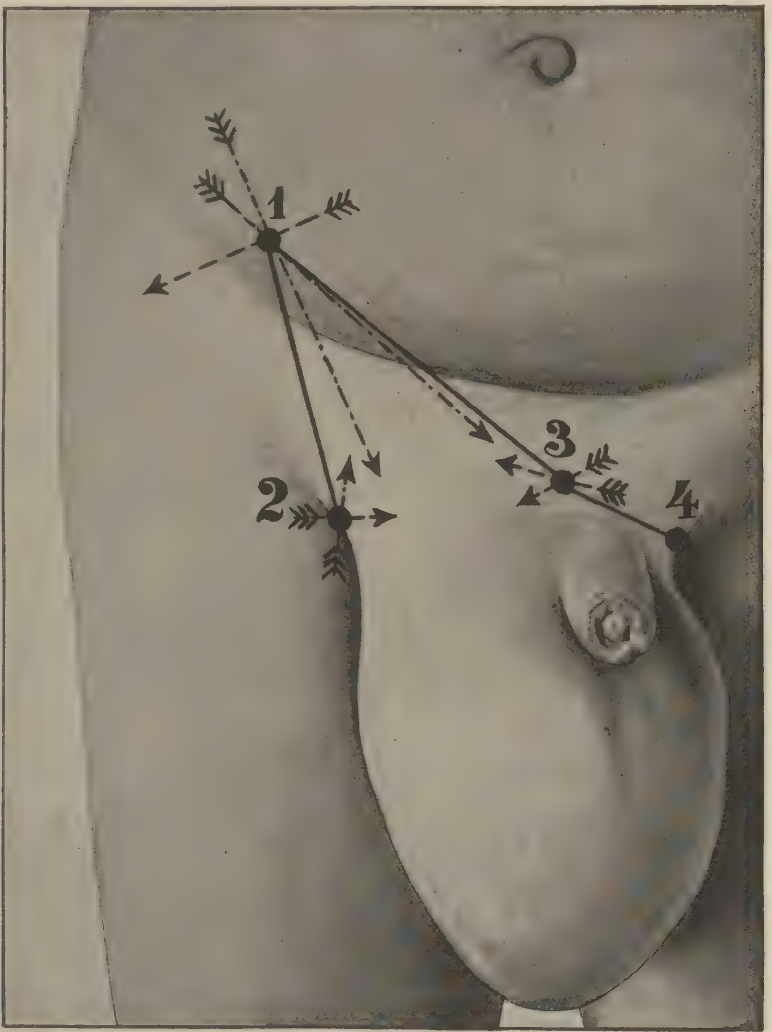


FIG. 147.—Injections for irreducible inguinal hernia or for reducible hernia with very large sacs. ——— subcutaneous, ... , subaponeurotic injections.

3, the hernial mass being held up with the left hand, either to the outside or inside as the case requires. From both of these points, the needle must reach the pubic bone underneath the hernial mass. Further injections are made from points 2 and 3 under the aponeurosis into the inguinal

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canal, alongside the neck of the hernial sac. The final injection is a subcutaneous one between points 1, 2, 3, and a subcutaneous circuminjection of the whole scrotum and penis as the diagram shows. In very

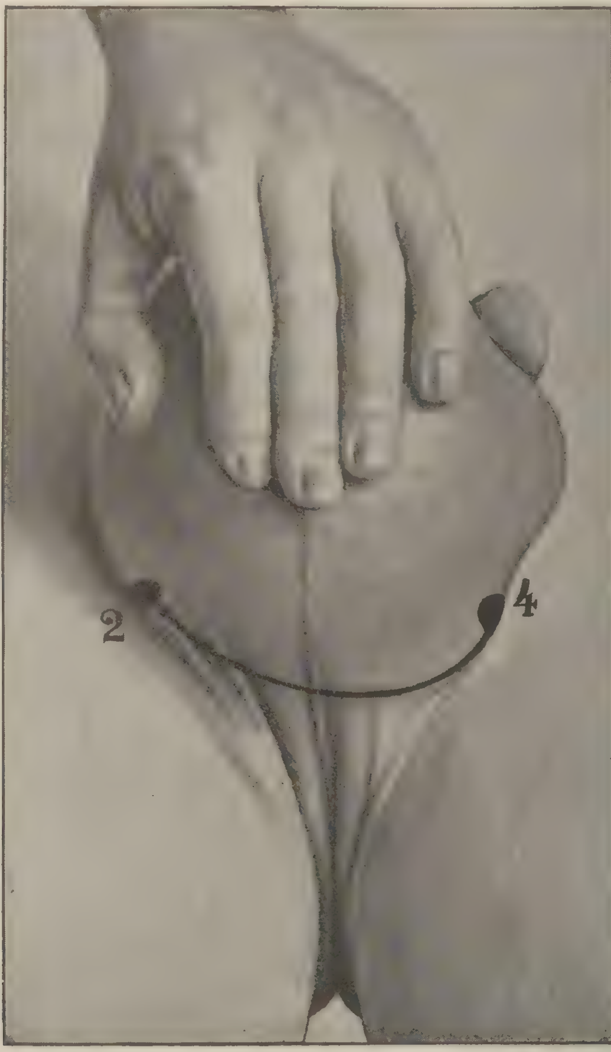

Fig. 148.—Continuation of the injection as shown in Fig. 147.

large herniæ 150 cc of 0.5 per cent novocaine-suprarenin solution will be necessary. Reducible herniæ, with large sacs reaching to the base of the scrotum, are also better managed in the way just described, that is, by circuminjecting the entire scrotum.

Procedure in Femoral Hernia.—A glance at Fig. 143 will show that the field of operation for femoral hernia is mainly innervated by the same nerve trunks which played an essential part in the anesthesia of the field of operation for inguinal hernia operations. Anesthesia for femoral

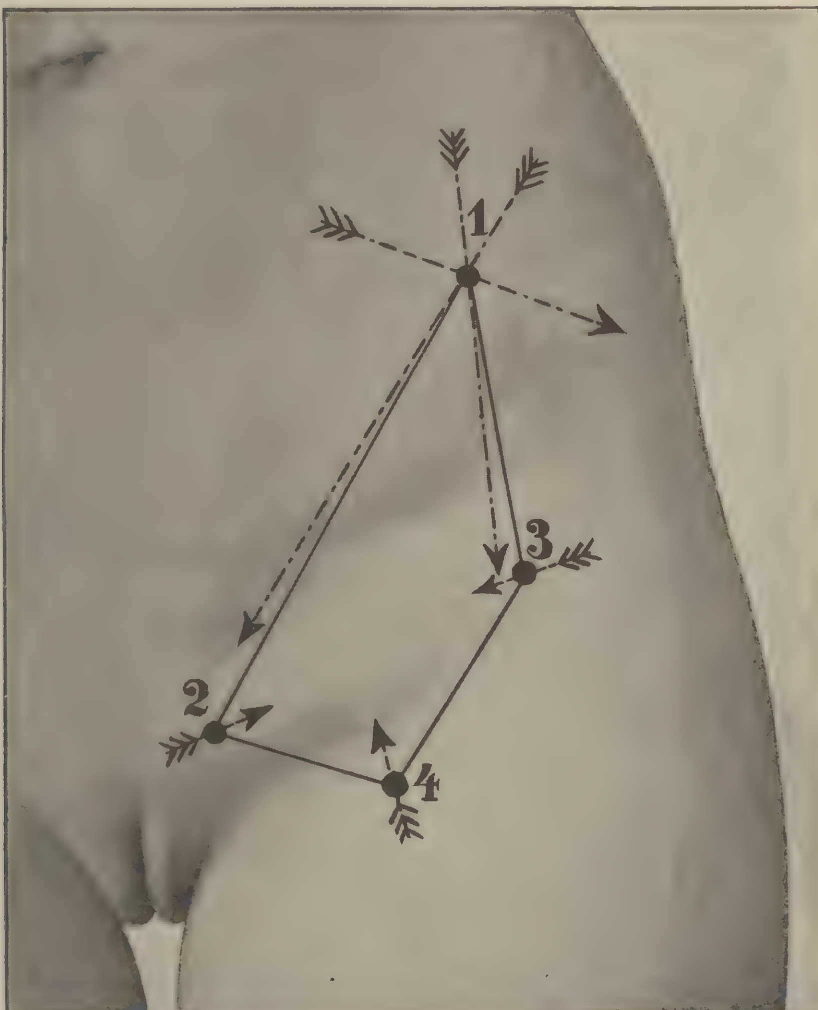

FIG. 149.—Anesthesia for femoral hernia.

hernia is produced in the following manner (Fig, 149). There are four points to be marked by wheals. Point 1 occupies the same position as it does in operations for inguinal hernia, three finger-breadths from the spine of the ilium toward the median line. Points 2 and 3 lie on each side

of the hernial mass and at the ends of the incision to be made, which is parallel to Poupart's ligament. Point 4 lies underneath the hernial mass. We begin with the intramuscular injections from point 1, which should be directed toward the spine of the ilium as they were in the case of inguinal hernia, then a fork-shaped, subfascial injection from point 1 is made, passing the needle on each side of the hernial sac as far as Poupart' ligament. From point 4, 10 cc of novocaine-suprarenin solution is injected in the region of the neck of the hernial sac, as close to it as possible, and finally a subcutaneous circuminjection is made, as indicated by the line in the diagram. The operations are entirely painless and no further injections will be necessary for the radical operation, even if the complication arises which necessitates the cutting of Poupart's ligament upward. The same method used for inguinal operations can also be used for femoral hernia without any change. In the method of anesthesia the size and consistency of the hernia need not be taken into consideration whether it be reducible or irreducible, strangulated or not. No difficulties are encountered in this anesthesia, except occasionally in obese and excitable patients. In the latter case morphine or morphine-scopolamine should be given. Other patients need not be prepared by the administration of any opiate. Abdominal sensations seldom occur except, perhaps once in a great while, when a hernial sac is separated and drawn out, and occasionally in gangrenous hernia when the mesentery is ligated. They are bearable, and only in exceptional cases is it necessary to use ethyl chloride.

Haertel has sought to simplify the method of injecting for umbilical and femoral herniæ in the following manner. The needle is introduced at a point a finger's breadth upward and inward from a point midway between the femoral artery, which can be recognized by its pulsation and the anterior-superior spine of the ilium. From this point, the needle is introduced fan-shaped through the aponeurosis, first perpendicularly along the inner surface of the Poupart's ligament into the psoas muscle then more superficially under the aponeurosis of the external oblique. By this method all of the nerves in question, including the spermatic nerve, are blocked and it only remains to make a subcutaneous circuminjection of the field of operation. According to the author, it is still necessary to inject the spermatic cord in order to block the sympathetic nerves which accompany it.

CHAPTER XV.

GENITO-URINARY AND RECTAL OPERATIONS.

The Innervation.—The innervation of the organs of the pelvis, and to some extent that of the external genitalia, is supplied by the pudic nerves, pelvic branches of the posterior cutaneous femoral, by spinal nerves, originating in the plexus which accompany the sympathetic nerve bundles of the pelvic organs, and by the nerves of the coccygeal plexus. Their distribution in the perineum and the external genitalia can be seen from Figs. 150 and 151. The trunk of the pudic nerve emerges from the pelvis through the large ischiatic foramen, passes along the outer surface of the spine of the ischium to be divided into its branches, which again enter the pelvis between the tuberosity and the spine of the sacrum.

Fig. 152 shows the position of the nerve trunk on the outer surface of the spine of the ischium. Its branches lie in the ischiorectal fossa and supply the skin of the perineum, parts of the anus, the skin of the posterior surface of the scrotum, the urethra and corpora cavernosa, the penis, in females the labia minora, the greater part of the vagina, and a part of the labia majora. The pelvic branches of the posterior cutaneous femoral, and the nerves which pass through the inguinal canal supply the anal region and the perineum, the skin of the scrotum and the labia majora; the nerves originating from the coccygeal plexus also supply the anal region. The spinal nerves, known as the pelvic nerves, originate from the second, third, and fourth sacral nerves, run forward on both sides of the rectum, and in the female unite with the sympathetic ganglion (ganglion cervicale uteri, Fig. 153) which lies between the cervix uteri and the rectum. In the male, it lies laterally between the prostate and the rectum.

The pelvic nerve innervates the bladder, uterus, prostate and the upper part of the rectum, as well as the lower part of the pelvic peritoneum.

CONDUCTION ANESTHESIA IN THE PELVIS.

Ilmer has recommended for operations on the female and for confinements that the trunk of the pudic nerve be blocked on both sides by injections of 5 to 10 per cent cocaine solution. The anesthesia used by him is absolutely unreliable and dangerous. Ilmer relies upon the methods of B. Mueller, which appear to be altogether theoretical and not at all based on practical experience. For anesthesia as extensive as Mueller mentions cannot be accomplished by blocking both pudic trunks. Furthermore, the operator cannot always rely upon meeting the trunk of the nerve on the inner surface of the pelvis, because it is covered by the obtu-

rator fascia and divides before its entrance into the ischiorectal fossa. For this reason Franke and Posner recommend that search be made for

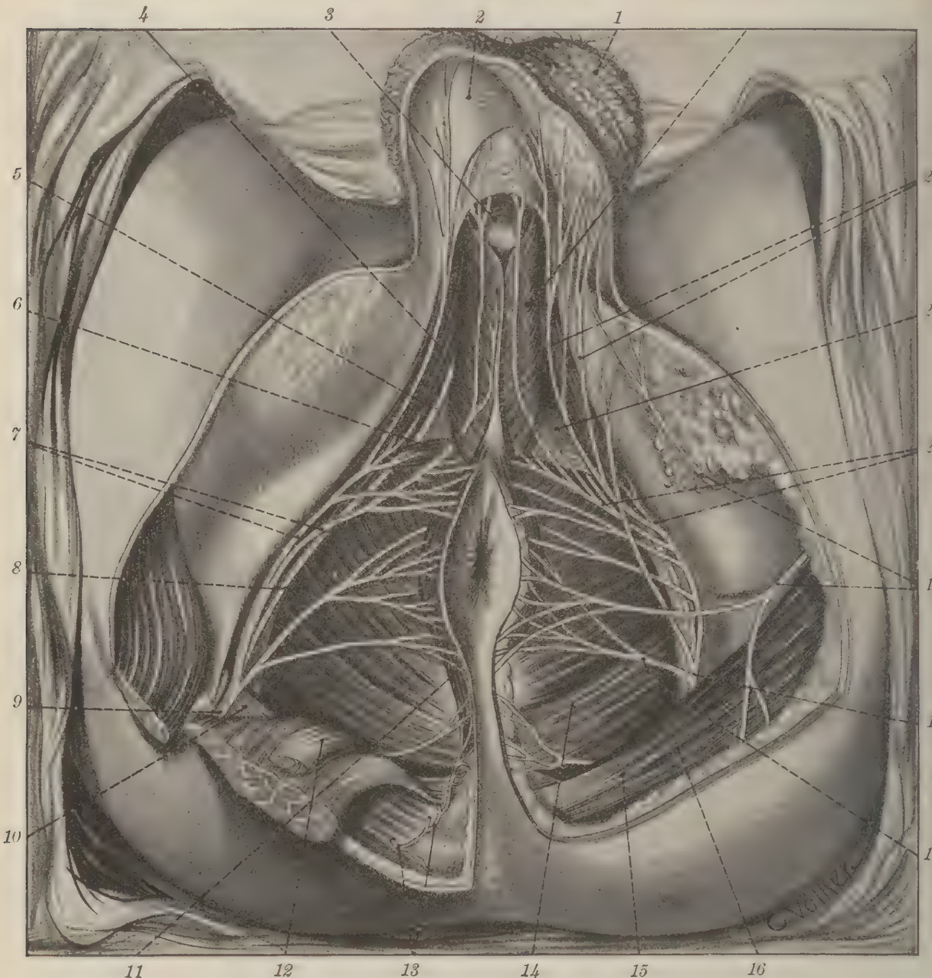

FIG. 150.—Nerves of the male perineum. (After Toldt.) 1, scrotum; 2, tunica dartos; 3, corpus cavernosum urethræ; 4, ischiocavernous muscle; 5, dorsalis penis nerve; 6, transversus perinei superficialis muscle; 7, perineal nerve; 8, dorsalis penis nerve; 9, pudic nerve; 10, ligamentum sacrospinosum; 11, sphincter ani externus muscle; 12, ligamentum sacrouberosum; 13, anococcygei nerves; 14, levator ani muscle; 15, gluteus maximus muscle; 16, inferior hemorrhoidal nerve; 17, ischiorectal fossa; 18, perineal nerve; 19, perineal branches of posterior cutaneus femoris nerve; 20, branches of perineal nerve; 21, transversus perinei profundus muscle; 22, postscrotal nerves.

the nerve on the outer surface of the spine of the ischium (Fig. 152), where it lies in the loose connective tissue. Guided by a finger placed in the rectum, they insert a needle 15 cm. long from a point on the side of the

anus, until the spine of the ischium is felt, and then direct the needle backward to the outer surface of the bone. It is sometimes difficult to feel the spine of the ischium and reach it with a needle when inserted so

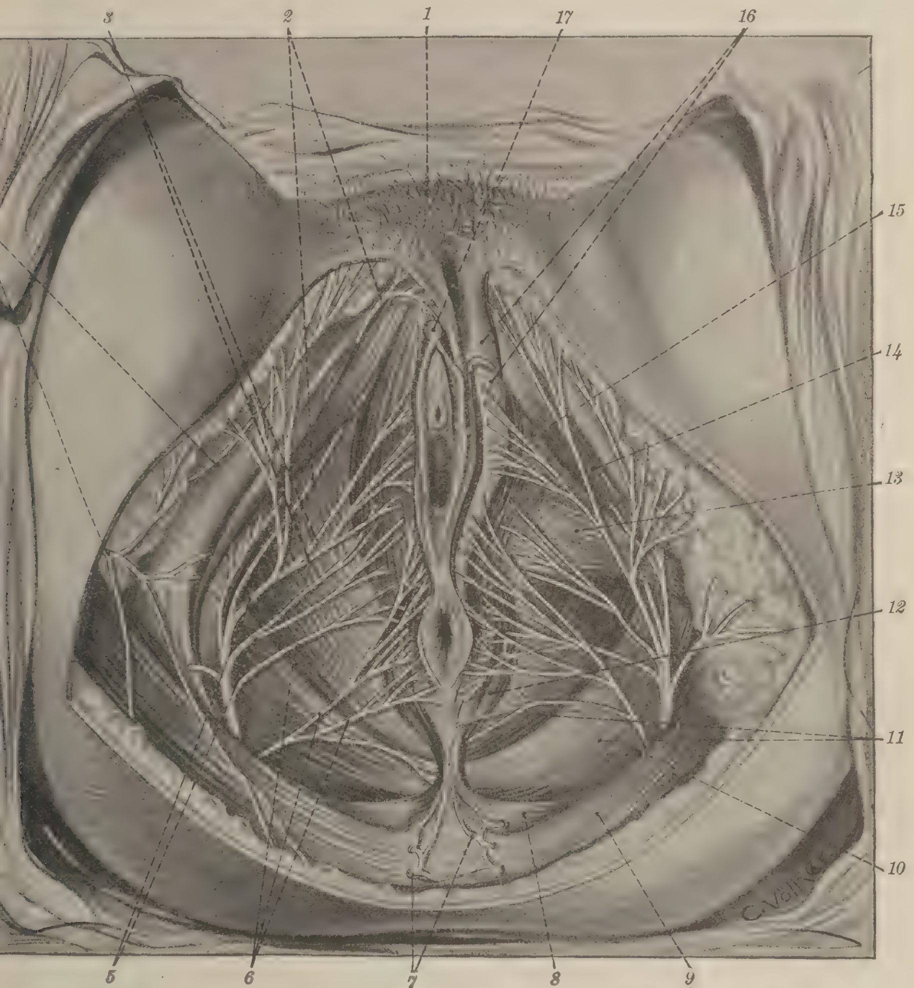

FIG. 151.—Nerves of the female perineum. (After Toldt.) 1, mons pubis; 2, dorsalis clitoridis nerve; 3, posterior labial nerves; 4, perineal branches of the cutaneus femoris posterior; 5, perineal nerve; 6, profundus hemorrhoidal nerve; 7, anococcygei nerves; 8, coccygeus muscle; 9, gluteus maximus muscle; 10, ischiorectal fossa; 11, levator ani muscle; 12, sphincter ani externus muscle; 13, transversus perinei profundus muscle; 14, ischiocavernous muscle; 15, bulbocavernosus muscle; 16, labium majus; 17, clitoris.

deeply. Blocking the trunk of the pudic nerve alone without the posterior cutaneus femoral, the coccygeal plexus, and the pelvic nerve is of little value. It is much easier to exclude its branches by proper injec-

tions, as will be seen later. The pelvic branches of the posterior cutaneus femoral are easily blocked, together with the branches of the pudic nerve, by injections into the ischiorectal fossa, and the coccygeal plexus is found by making an injection between the coccyx and the rectum. Franke and Posner attempted to locate the pelvic nerve by making injections in the region of the sympathetic ganglion of the cervix of the uterus (Fig. 153). For this purpose a needle 15 cm. long was inserted at a point in front and to the side of the anus, between the rectum and the prostate, as

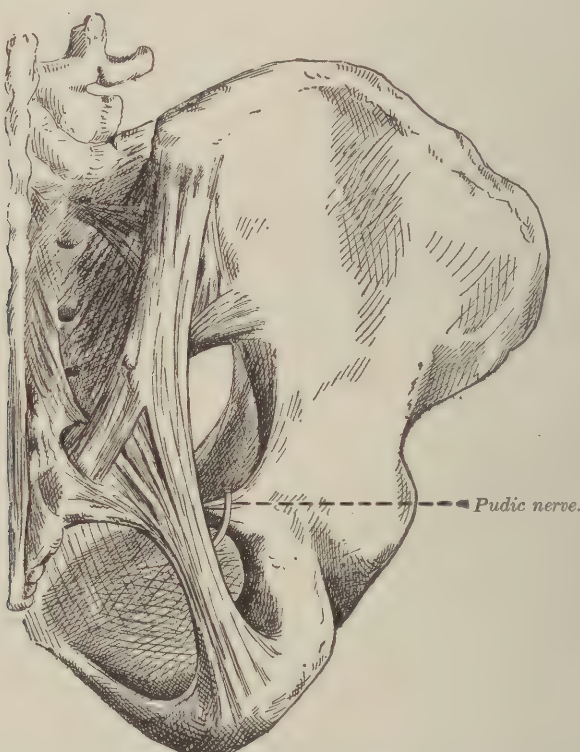

Fig. 152.—Position of the pudic nerve on the spine of the ischium.

high as the region of the ganglion, injecting 15 cc of 1 per cent novocaine-suprarenin solution on both sides. In connection with the above-named injection of the trunk of the pudic nerve, and injections into the ischiorectal fossa, they were able to make painless perineal prostatectomies and one lithotripsy. All of these experiments have at present an historical interest as illustrating the development of local anesthesia of this part of the body. It is, however, more important and technically much simpler to block the sacral nerves at their points of emergence from the sacral foramen. In this way the pelvic nerve, the entire pudendal plexus, and

the posterior cutaneus femoral nerve are interrupted and a complete anesthesia of the pelvic organs and lower part of the pelvic peritoneum is obtained. This procedure we will call *parasacral conduction anesthesia*, deriving the idea from the paravertebral anesthesia of Sellheim and Laewen (page 290), in which the injection was also made into the nerve trunks as they leave the spinal canal.

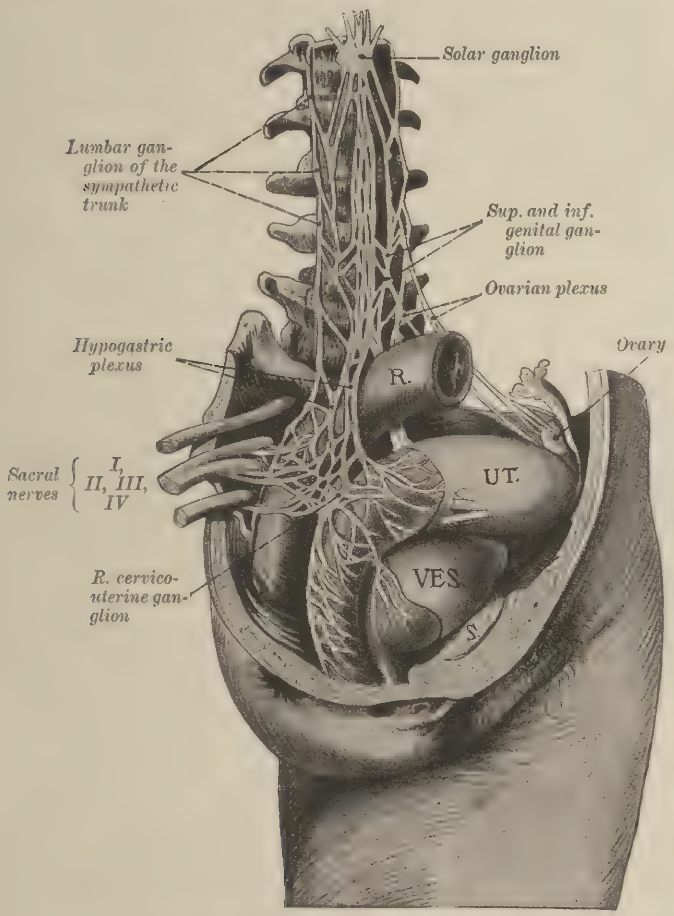

FIG. 153.—Innervation of the pelvic organs. (After Corning.)

For operations on the pelvic and sexual organs, it is a very useful method, simple in its technic, therefore easy to learn and perfectly safe and certain. It is superior to lumbar anesthesia because it is free from danger and because the resulting anesthesia is of longer duration and it is superior to epidural or sacral injection, because there are practically no failures. The technic of parasacral anesthesia is

as follows: An inspection of the inner surface of the sacrum shows that in the lower part there is very little curvature to the bone, so that one may pass a needle upward from a point near the sacrococcygeal joint along the inner surface of the sacrum past the fifth, fourth, third, and second sacral foramina almost without losing contact between the point of the needle and the bone. Above the second sacral foramen the point of the needle must necessarily strike the bone and cannot be inserted farther. In the adult, this point is from 6 to 7 cm. distant from the lower end of the sacrum. If it is desired to reach the first sacral foramen the outer end of the needle must be depressed somewhat and the needle introduced again in this direction. At a distance of from 9 to 10 cm. from the lower end of the sacrum the needle strikes the bone at the overhanging edge of the first sacral foramen. It is not intended that the needle should enter the sacral foramina; that unfortunately is impossible, it is merely necessary to fill the hollow of the sacrum with a weak novocaine-suprarenin solution. The patient is placed in the lithotomy position. A wheal is made in the skin about $1\frac{1}{2}$ to 2 cm. to the right and another to the left of the tip of the coccyx. A needle 12.5 cm. in length is introduced in one of the wheals and search is made with the point for the lower end of the sacrum near the sacrococcygeal joint. The point of the needle is then passed by the end of the sacrum and along the inner surface of this bone parallel with the midline until it strikes against the bone at the depth mentioned. The point will then be at the upper edge of the second sacral foramen. While the needle is slowly withdrawn with short pauses, 40 to 50 cc of a 0.5 per cent novocaine-suprarenin solution are injected which infiltrate the neighborhood of the second to fifth sacral foramina. The needle is now withdrawn until the point is in the subcutaneous tissue and reintroduced at an angle directed more toward the innominate line but constantly parallel with the midline. It is pushed deeper in this direction until the point of the needle strikes against the bone at the upper edge of the first sacral foramen. At this point, from 30 to 40 cc of the solution are injected. The coccygeal plexus must likewise be interrupted and not only its anterior but also its posterior branches which take part in the innervation of the skin about the anus and perineum. This is accomplished by injecting 5 to 10 cc of the solution in front of the coccyx, between it and the rectum, and the same amount on the posterior surface of the coccyx. The same procedure is repeated on the opposite side. Occasionally the skin of the perineum, scrotum and labiæ receive some innervation from the side from the upper part of the thigh which is not affected by the parasacral injection, therefore the author recommends before operating on the anus, perineum or vagina: (1) To inject subcutaneously a narrow strip connecting the two points for the parasacral injection (5 cc of a 0.5 per cent solution); (2) to inject with the same long needle used for the parasacral injection a subcutaneous strip on either side extending forward along the anus, perineum, scrotum or labiæ (10 cc each side) (Fig. 154).

The author agrees with Siegel that it is better to use more of a 0.5 per cent than less of a 1 per cent novocaine-suprarenin solution and uses as

a rule from 75 to 100 cc of the former on each side. By this method the anesthesia includes the anus and the rectum up to the sigmoid, the peri-

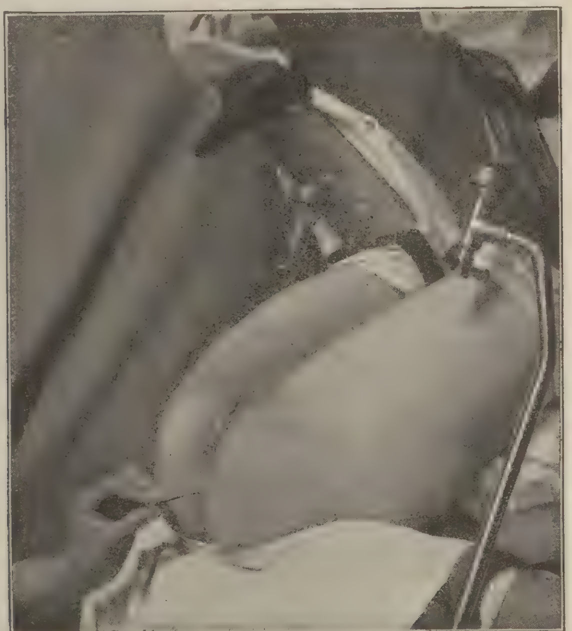

FIG. 154.—Parasacral injection.

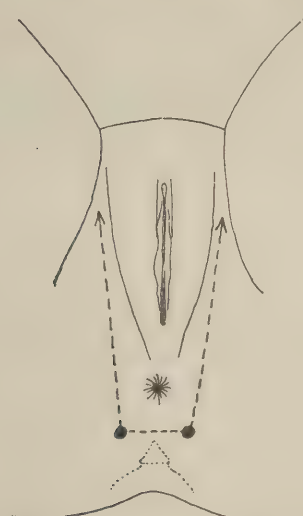

FIG. 155.—Extension of parasacral injection: circuminjection of the anus and perineum.

neum, urethra, and bladder and in the male the scrotum, penis, and prostate and in the female the vulva, vagina, uterus, the pelvic peritoneum and the perimetrium. The sphincter ani and vaginæ are paralyzed. Under this anesthesia operations may be performed on the urethra, prostate, bladder, rectum, and the vagina. The anesthesia appears as a rule very quickly after the injection and is always complete by the time the preparations for the operation are finished. Parasacral anesthesia is free from the secondary effects of paravertebral anesthesia. In 412 cases in which the author used this method, there were no indications whatsoever of novocaine poisoning and in only 18 cases was the blocking of the sacral plexus incomplete. Danis and Reinhardt have described a method in which the needle is introduced through each of the ten sacral foramina

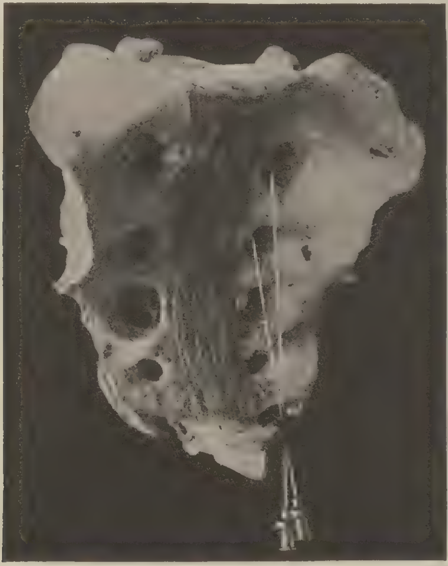

FIG. 156.—Position of the needle for parasacral conduction anesthesia.

from behind, thus bringing the solution in contact with the roots of the sacral nerves. The author believes that this method will not come in competition with the parasacral method described above.

KIDNEY OPERATIONS.

Laewen describes a pyelotomy for kidney-stone which was successfully performed under local anesthesia. From each of 4 points about 4 cm. from the median line he made paravertebral injections into the twelfth intercostal and the first to the third lumbar nerves, using 10 cc of 1 per cent novocaine-suprarenin solution and circuminjected the field of operation with a 0.5 per cent novocaine-suprarenin solution. The luxation of the

kidneys was the only part of the operation not entirely painless. For kidney operations Kappis recommends the simple paravertebral conduction anesthesia without the concomitant circuminjection. For this purpose the eighth dorsal to first lumbar nerves must be blocked; for operations on the ureter, the second and third lumbar nerves must be blocked. Kappis states that since the development of this method almost all kidney operations are performed under local anesthesia at the Kiel clinic. (Concerning the technic of the paravertebral injections see page 289.) Encouraged by this statement, the author used Kappis' technic and removed successfully a large hypernephroma. The patient experienced no pain during this tedious operation, except on ligating the pedicle, whereupon several whiffs of ether were administered.

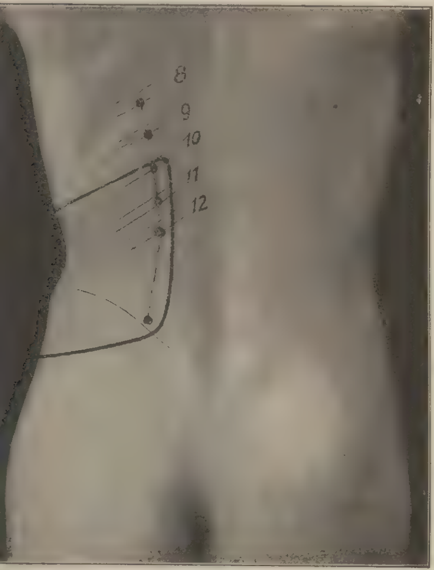

FIG. 157

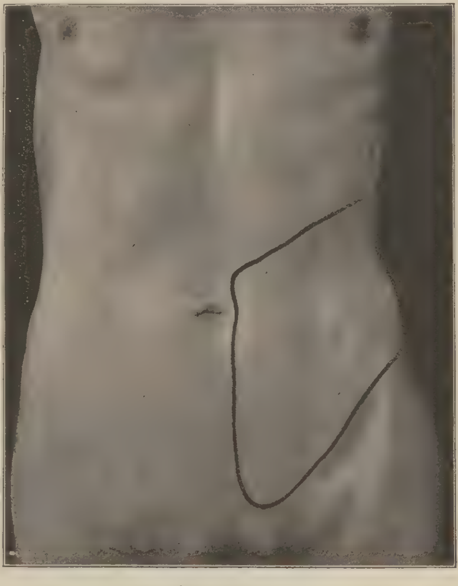

FIG. 158

FIGS. 157 and 158.—Technic of anesthesia for kidney operations. The continuous line indicates the extent of anesthesia.

Kappis reports 32 operations on the kidney under paravertebral anesthesia. Some of the operations were entirely painless; in some cases a small amount of narcosis was necessary to help out in 2 cases the anesthesia was insufficient. In addition to light symptoms of poisoning 1 fatal case was observed at the conclusion of the paravertebral injections. At the autopsy made immediately after death the spinal fluid was found to contain novocaine. According to the author's experience paravertebral anesthesia in kidney operations is superfluous as intercostal anesthesia carried out at some distance from the vertebral column is entirely sufficient. The injections are made in the manner shown in Figs. 157 and 158. Two points of entrance

are made along the lateral border of the quadratus lumborum muscle, one at the twelfth rib, the other at the crest of the ilium. The muscular tissue between these two points is infiltrated with a 0.5 per cent novocaine-suprarenin solution (about 75 cc), the infiltration extending into the peritoneal fat as far as the bodies of the vertebræ. The eighth to the eleventh dorsal nerves are blocked along the same line by injecting about 10 cc of the same solution into each intercostal space. In order to lessen the rather short waiting time the subcutaneous tissue may be infiltrated. The extent of the anesthesia in three examined cases corresponded to the area shown in Figs. 157 and 158. The results of this method are very gratifying. When ligating the kidney pedicle or when examining the opposite kidney after the peritoneum has been opened, it may be necessary to give a few whiffs of a general anesthetic. No unfavorable effects on the kidney of the novocaine have been demonstrated. At all events it is much less than that following any other anesthetic. For that reason local anesthesia is to be preferred when it is shown that disease of the kidney is present or suspected.

ANESTHESIA OF THE MUCOUS MEMBRANE OF THE BLADDER AND URETHRA.

The application of a concentrated solution of cocaine to so large an absorbing surface as the bladder and the male urethra is, as is well known, dangerous to life. Numerous patients have died from the effect of this unreliable method of cocaine application. Sudden death has resulted from an injection into the urethra of 5 cc of a 1 per cent cocaine solution (Czerny). The secondary toxic effects of the drug administered in this manner are due to the concentration of the solution and not to the quantity used. Weak cocaine solutions (0.1 to 0.2 per cent in the bladder, 0.5 per cent in the urethra) with the addition of suprarenin are absolutely safe and produce the same degree of anesthesia as concentrated solutions, if kept in contact with the mucous membrane a sufficient length of time.

Of the newer remedies, a combination of alypin and suprarenin is the best substitute for cocaine. The application of a concentrated solution of this remedy is to be used with caution. Garrasch has twice experienced severe poisoning (see page 115) following injections of 5 cc of 2 per cent and 5 per cent solutions of alypin into the urethra. Proskauer had a death following the use of alypin in the bladder.

In order to render the mucous membrane of the bladder insensitive to the touch of instruments and for superficial operations the bladder should be filled with a 0.5 per cent solution of alypin and suprarenin and allowed to remain from fifteen to thirty minutes. If the mucous membrane of the bladder is not sufficiently cleansed before the solution is injected, if the bladder is filled with blood, or if the mucous membrane is incrusted or covered with adherent mucus, it will be impossible to bring the solution sufficiently in contact with the mucous membrane to obtain anesthesia.

In intravesicular manipulations, made through the urethra, it is more important to anesthetize the more sensitive posterior part of the urethra than the mucous membrane of the bladder. In the male urethra the mucous membrane, when the urethra is penetrable, is made insensitive in the following manner: A thin Nélaton catheter is introduced into the bladder and drawn back until the fluid ceases to run; 5 cc of a 1 per cent alypin-suprarenin solution (for the proportion see page 187) is injected. At the same time the catheter is gradually withdrawn, the fluid prevented from escaping, and the penis tied off with tape. The solution should remain in the urethra at least ten minutes or a quarter of an hour. This is absolutely necessary, the intensity and duration of the local anesthesia depending upon the length of time the solution remains in contact with the parts.

If the urethra is not passable, an anterior injection is made and the penis ligated. In strictures it is necessary to repeat the injection when the stricture has become passable. This procedure makes catheterization and dilatation of strictures entirely painless. In order to render the mucous membrane of the female urethra insensitive, all parts of the membrane, from the external orifice to the neck of the bladder, must be swabbed with a 2 per cent alypin-suprarenin solution, and the applications repeated for several minutes. The anesthesia thus produced will not be sufficient for extreme dilatation of the urethra which is sometimes necessary. In all material operations on the urethra or bladder mucosa parasacral anesthesia is to be preferred to intra-urethral or intravesical injections.

Fig. 159.—Injection for suprapubic cystotomy.

OPERATIONS ON THE BLADDER.

Suprapubic Cystotomy.—The author performs suprapubic cystotomy for the removal of stone or tumors almost without exception under local anesthesia. After the usual parasacral anesthesia, the abdominal wall in

the line of incision is infiltrated with a 1.5 per cent novocaine-suprarenin solution and the prevesical space filled with the same solution.

OPERATIONS ON THE SCROTUM AND TESTICLES.

The skin of the scrotum and the tunica vaginalis communis receives its innervation for the most part from the perineum, from the subcutaneous branches of the pudic nerve and the posterior cutaneus femoral. Above it is also supplied by branches of the ilioinguinal and the external spermatic as they emerge from the inguinal canal. The last two named nerves alone supply the spermatic cord, the testicles and the tunica vaginalis propria. For the complete anesthesia of these parts the following injection is necessary. One point of entrance is marked on each side where the spermatic cord crosses the pubic bone, another is marked laterally where the scrotal skin emerges with the skin of the thigh (Fig. 160).

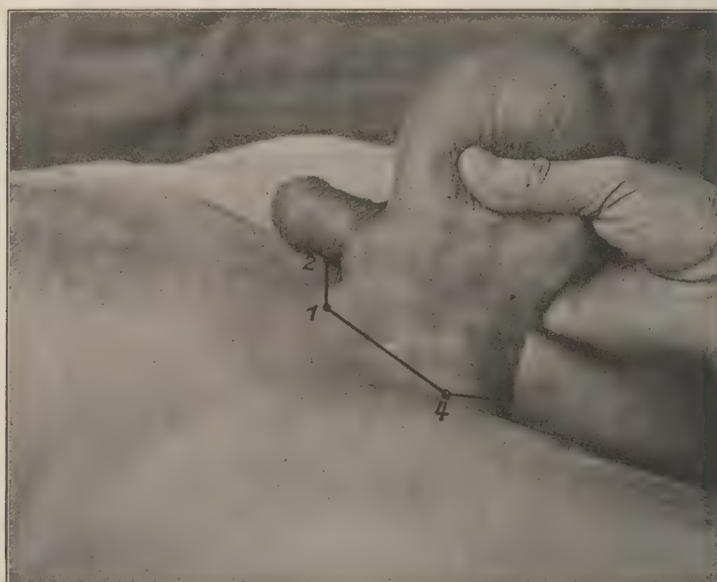

Fig. 160.—Circuminjection of penis and scrotum for operations upon the scrotum and testicle.

The next step is to produce anesthesia in the spermatic cord with its nerves. Reclus lifts the spermatic cord with two fingers of the left hand and injects the anesthetic into the cord (Fig. 161). It is not always possible to lift up the cord as, for example, in a large hydrocele that extends high up, for which reason the following method is preferable: A needle is inserted from 1 toward the underlying pubic bone until the bone is felt with the point of the needle, and a bilateral fan-shaped injection of 5 cc of 0.5 per cent novocaine-suprarenin solution is made in three directions,

perpendicular and lateral to the symphysis. In Fig. 162 the needles indicate the two last mentioned directions. In this way the spermatic

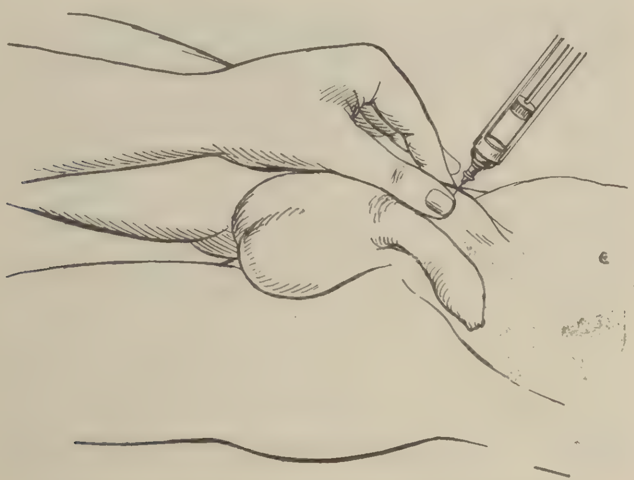

FIG. 161.—Injection into the spermatic cord. (After Reclus.)

cord cannot be missed. Finally, an extra injection of 10 cc of 0.5 per cent novocaine-suprarenin solution is injected into the inguinal canal

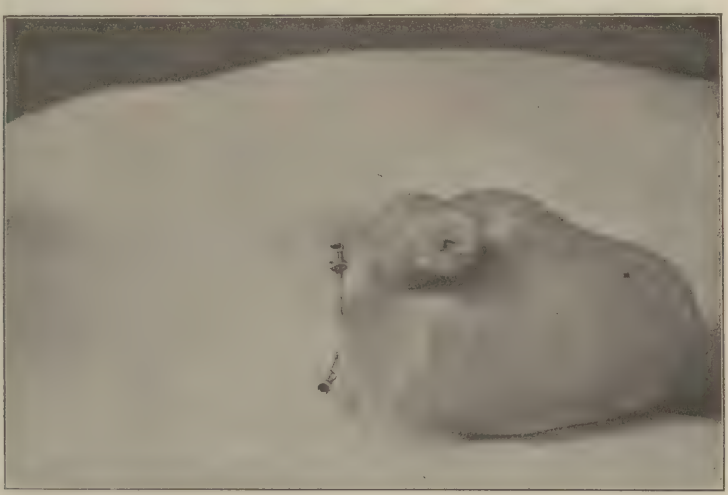

FIG. 162.—Fan-shape injection upon the pubic bone for hydrocele.

(Fig. 163), in this manner obtaining a reliable blocking of the nerves accompanying the spermatic cord. In bilateral operations this manipu-

lation must naturally be carried out on both sides. These injections must be followed by a subcutaneous circuminjection of the entire scrotum,

FIG. 163.—Injection in the inguinal canal for hydrocele.

FIG. 164.—Circuminjection of the posterior surface of the scrotum.

whether the condition be uni- or bilateral, made in a line connecting the four points of entrance (Fig. 160). Fig. 164 demonstrates the position of

the needle for the subcutaneous injection from point 4 toward the perineum. In fat persons it is necessary to infiltrate freely the circular line of injection in layers, in order to block with certainty the posterior scrotal nerve. Not infrequently, 50 cc or more of 0.5 per cent novocaine-suprarenin solution is necessary for the circuminjection. This procedure is suitable for all operations on the scrotum and testicles and is also specially suitable for the radical operation for hydrocele and for ablation of the testes.

If these operations are performed through Kocher's inguinal incision the spermatic cord is immediately exposed at the beginning of the operation. If, after exposing the tunica and the testicle, it is found that the injection of the cord has not been successful, an accident which is very apt to happen to a surgeon who is not at once familiar with these methods, it will be necessary to inject a few drops of a 2 per cent novocaine-suprarenin solution into the spermatic cord in order to obtain the desired anesthesia.

OPERATIONS ON THE PENIS.

For a simple dorsal incision of the prepuce in phimosis it is only necessary to infiltrate the line of incision by an injection between the skin and mucous membrane. A very fine needle is inserted into the edge of the foreskin (Fig. 165) and passed between the skin and the mucous membrane

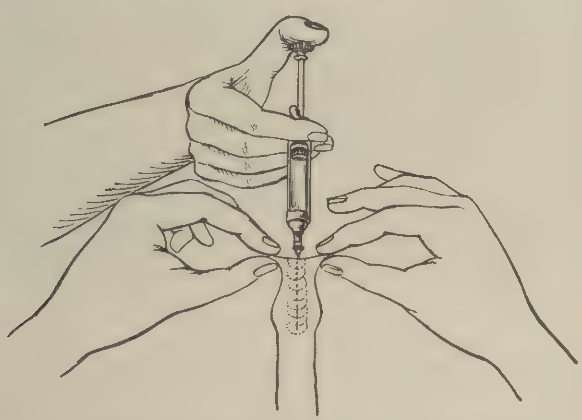

FIG. 165.—Injection for the dorsal incision of the prepuce.

upward over the coronary sulcus, injecting along this line 1 to 2 cc of 1 per cent novocaine-suprarenin solution. Occasionally it is easier to make the injection from a point on the dorsum of the penis. The needle in this case is pushed forward subcutaneously to the edge of the prepuce.

Anesthesia of the entire prepuce for phimosis is produced as follows: The foreskin is drawn tensely over the glans and is held in this position by tying with tape. The anesthetic is injected subcutaneously and circularly into the coronary sulcus, and the tape is not removed until

after the anesthesia has become complete. In cases of paraphimosis it is necessary to make a circular injection into the coronary sulcus, and one above the constricting band. Injections of suprarenin solution into the peripheral parts of the penis must be made with caution as the arteries supplying the prepuce are end arteries. If the novocaine-suprarenin solution is injected too freely, the effect of the suprarenin may last too long, and a prepuce treated in this manner will be in a similar condition to a pedicled skin flap (see page 143). As a result of the contraction of all the arteries the tissues are unable to throw off the injected substances, or do it too slowly and in this way cause damage to the tissues. The author has not seen damage of this kind but he never injects more than 1 or 1.5 cc of 1 per cent novocaine-suprarenin solution into a penis. It is therefore advisable that the circular, peripheral injection into the penis

Fig. 166.—Anesthesia of the entire penis.

be avoided and that the entire penis be made insensitive by injections at its base, even in operations for phimosis. If a circular subcutaneous injection of an anesthetic is made around the shaft of the penis, as described by Krogius, the glans and mucous membrane of the foreskin are often not made insensitive, giving rise to serious complaint in operations for phimosis. This is not the case if the injection is made close to the symphysis in the following manner (Fig. 166):

Anesthesia of the Entire Penis.—Two points of injection are made, one to the right and one to the left of the base of the penis, at a point where the spermatic cord crosses the horizontal ramus of the pubes. From these two points, with the penis drawn out and held in this position, a 0.5 per cent novocaine-suprarenin solution is injected. The needle is then passed as deep as the corpora cavernosa, circuminjecting them at

the point where they emerge from the angle of the symphysis and unites with the shaft of the penis. From below the needle penetrates the scrotum, above it reaches the suspensory ligament of the penis. In fat persons long needles are necessary. A second injection just under the skin is then made corresponding with the dark line in Fig. 166. In an adult with a moderate amount of fat about 75 cc of 0.5 per cent solution are required, a proportionately smaller quantity being used in children. The entire penis, skin, prepuce, glans, the pendulous portion of the urethra, and the corpora cavernosa, distal to the pubes, are rendered insensitive. This method is suitable for all operations on the parts named—for example, in amputation of the penis, plastic operations on the urethra (hypospadia glandis), urethral fistulæ and, as has been stated, for phimosis and paraphimosis.

For extirpation of inguinal glands in connection with amputation of the penis see Chapter XVI.

OPERATIONS ON THE POSTERIOR PART OF THE URETHRA. EXTERNAL URETHROTOMY.

For years external urethrotomy for strictures and recent injuries have been performed almost without exception under local anesthesia in the following manner: In the median line in front of the anus one point is marked (Fig. 167) and an imaginary horizontal plane is drawn through this point. In the diagram this is shown by a horizontal line. This plane separates the anus and the rectum on one side from the bulbus urethræ and the prostate on the other. Laterally it passes through the ischiorectal fossa on each side and meets the ascending ramus of the ischium in front of the tuberosities. This plane must be infiltrated with a 0.5 per cent novocaine-suprarenin solution. For this purpose the left index finger is inserted into the anus, and a needle 8 to 10 cm. long is inserted into the median plane between the bulbus urethræ and the anus, and a continuous injection is made, as high up as possible, between the rectum and the prostate. In the next two injections the needle is directed farther to the right and left, reaching the lateral lobes of the prostate and rectum. In the next two injections it is passed within the transverse plane and always from the same point of entrance still more laterally, penetrating deeply into the ischiorectal fossa. In the last two injections the needle is directed almost transversely to the right and left, striking the ascending ramus of the ischium. The final subcutaneous injection is not made in the horizontal plane but as shown in Fig. 167 in the direction between the scrotum and the thigh, in order to block those nerves of the skin which might extend from the side to the perineum and the scrotum; about 75 cc of 0.5 per cent solution is necessary. The course of the needle in deep injections is reproduced in Fig. 168.

All the branches of the pudic nerve and the posterior cutaneous femoral which supply the prostate, urethra and the external genitalia are blocked

with certainty (see Fig. 150, page 326). Franke and Posner have observed that the infiltration behind the prostate is an important factor in the blocking of the pelvic nerve. The perineum, the posterior surface of the scrotum, the entire urethra from the neck of the bladder to the external orifice and the prostate are rendered insensitive. The patient does not feel the entrance of the catheter and all operations performed in this region are painless. The perineal dissection of the prostate is usually not altogether painless, as violent pulling on the organs cannot be avoided. The method described has the same effect and is more reliable than Laewen's sacral anesthesia, and is preferable, as the anemia of the field of operation pro-

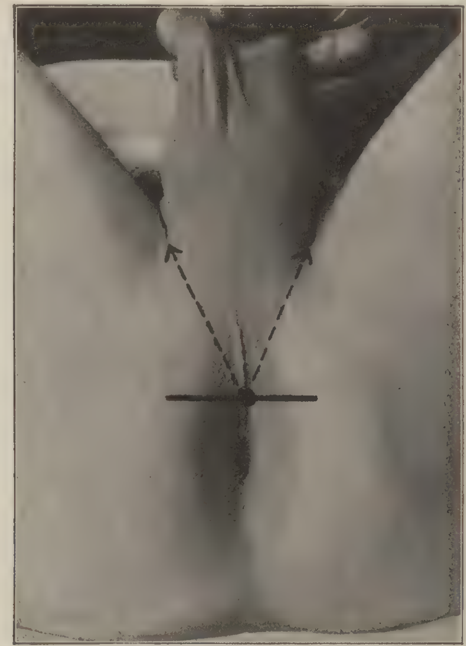

Fig. 167.—Transverse infiltration of the perineum for external urethrotomy.

duced by the suprarenin is of great value. Only when the injections cannot be made behind the urethra and prostate, as in urinary infiltration and in abscesses, is sacral anesthesia to be preferred to direct anesthesia of the field of operation. Sometimes the method described is combined with anesthesia of the entire scrotum (page 336) for amputation of the penis, for the median splitting of the scrotum, and for sewing the urethra into the perineum, according to the method of Thiersch.

Prostatectomy.—Parasacral conduction anesthesia is an ideal method of anesthesia for performing the perineal or Wilms' prostatectomy. In addition the author infiltrated the line of incision with 25 to 30 cc of a 0.5 per cent novocaine-suprarenin solution to diminish the bleeding.

For suprapubic prostatectomy the same method is followed as in bladder operations; namely, parasacral anesthesia with infiltration of the line of incision in the abdominal wall.

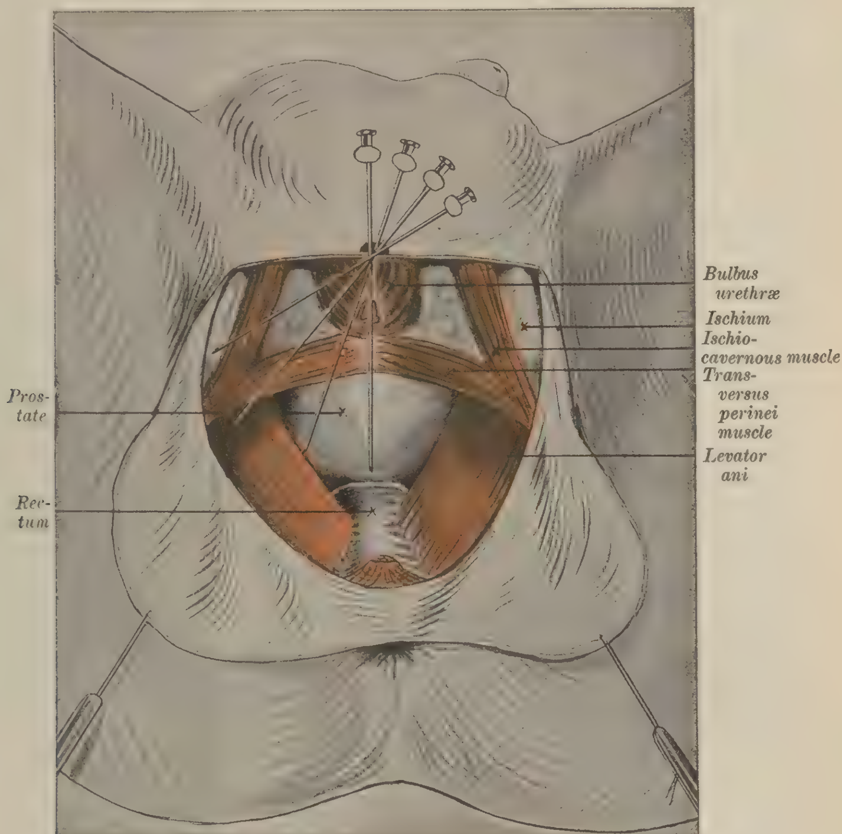

FIG. 168.—Transverse infiltration of perineum; position of needles.

VAGINAL OPERATIONS.

While the older reports of Reclus and Schleich regarding the use of local anesthesia for vaginal operations did not seem to find favor among gynecologists, nevertheless, they have recently begun to use local anesthesia in this field following the experience of operators in general surgery. Among the gynecologists Freund (1904) was the first to interest himself in local anesthesia. In colporrhaphies he recommended subcutaneous and submucous injections of 1 cc of 1 per cent eucaine solution with the addition of suprarenin to be introduced at each point for both anterior and posterior operations. For plastic perineal operations and colporrhaphies

Fisch and Wagner have also found local anesthesia satisfactory. Henrich, a pupil of Freund, also Fisch, Wernitz, and Kraatz, have used local anesthesia for operations on the cervix, for dilatation of the cervix and for curettements. Wernitz used unsuitable remedies (1 to 2 per cent cocaine solution) and, as was to be expected, experienced cocaine poisoning. Ruge reported two total vaginal extirpations under local anesthesia. Reclus had described such an operation some time before, but his case was one of prolapse of the uterus. Reference has already been made to anesthesia of the pudic nerve (page 328). Sellheim very appropriately remarks that conduction anesthesia of the pudic nerves can be much more reliably obtained by injecting large quantities of the solution to various depths and in various directions, in the neighborhood of the nerves as they emerge from the ischiorectal fossa. The use of the modern novocaine-suprarenin solution in gynecology was introduced by Fisch. In former editions of this work a method was described of rendering painless operations on the external genitals and in prolapsus by means of local injections under the skin and mucous membrane either alone or in combination with transverse infiltration, of the perineum between the rectum and the vagina and injections into the parametrium.

Ruga and Thaler have shown that it is possible to perform all sorts of vaginal operations, including the extensive operation of Schauta for carcinoma under local anesthesia by the injection of novocaine-suprarenin solution in the parametrium combined with submucous and subcutaneous injections. Ruga reports 22 vaginal operations, 19 of which were total extirpations under parametrial conduction anesthesia and describes the method of injection as follows: The needle is introduced in the parametrium on either side of the uterus to a depth of 4 to 5 cm. It is directed at once laterally in order to reach the nerves entering the parametrium as centrally as possible and in order to secure a wide distribution of the anesthetizing fluid in the floor of the pelvis. About 10 cc of 1 per cent novocaine-suprarenin solution is injected on either side. At each of two points on the anterior and posterior vaults of the vagina are injected 5 cc of the solution at a depth of 2 to 3 cm., making 40 cc of the 1 per cent solution used all together. The usual precautions are taken to prevent the intravenous injection of the solution.

Thaler in addition infiltrates completely the tissues to be divided and also anesthetizes the vaginal entrance by circuminjection. He reports 5 cases of extensive vaginal operations for carcinoma.

Operations on the Labia.—Large and small cysts and solid tumors of all kinds, both on the labia majora and minora, should always be removed under local anesthesia, according to the general rules given in Chapter X. For the removal of the tumor shown in Figs. 169 and 170 there were three points of entrance marked. Point 1 on the perineum, point 2 laterally, and point 3, which is not visible in the diagram, is placed above the tumor. From these three points 40 cc of 0.5 per cent novocaine-suprarenin solution were injected, part under the tumor, and a part used for the subcutaneous circuminjection, made in the direction of the dotted line. In case of a

malignant tumor it is more advisable to anesthetize the entire vulvar orifice, which method will be described later.

Repairing Recent Perineal Tears.—For repairing recent perineal tears it is advisable to inject under and around the entire wound with a 0.5 per cent novocaine-suprarenin solution. According to Mathes the points of entrance are placed in the mucous membrane of the vagina, which is already insensitive, or the injection is made according to Schmidt from the wound surface into the recto-vaginal septum. Schmidt estimates the amount necessary for this operation to be 60 to 70 cc of 0.5 per cent novocaine-suprarenin solution.

Fig. 169

Fig. 170

Figs. 169 and 170.—Extirpation of a tumor of the labia majora.

According to the author's opinion parasacral anesthesia has become the normal procedure in vaginal operations, as thereby the anus, the perineal region, the vaginal entrance, the vagina, the uterus, the urethra, the bladder, the pelvic floor, for the greater part of the pelvic peritoneum and the parametrium are made insensitive and the sphincter of the vagina is paralyzed. It has the advantage over lumbar anesthesia by reason of its safety and the longer duration of the anesthesia and over sacral or epidural injections so warmly recommended by gynecologists because of fewer failures. Failures occur only in the hands of beginners who are not familiar with the introduction of the needle. In vaginal operations the subcutaneous infiltration of the narrow strip as described on page 330 should not be omitted. Under local anesthesia by the parasacral method can be performed a great majority of vaginal operations, such as all operations on the vaginal inlet, plastic

operations for prolapsus and fistulæ of the bladder. Operations on the portio and on the uterus, particularly emptying of the uterus after rapid dilatation of the cervix or division of the cervix (vaginal Caesarean section), vaginal hysterectomy and vaginal total extirpation. The opening of the abdominal cavity through the anterior and posterior vaults of the vagina, the dissection of the ureters and the clearing away of the parametrium are not felt by the patient. Vaginotomy after Schuchardt-Schauta falls within the insensitive area. The adnexa and their attachments remain more or less sensitive at times. Strong traction on the broad ligaments causes painful sensations at times which are more noticeable to the patient for the reason that the preceding part of the operation has not been perceived. The separation of adhesions are painful if they involve portions of the pelvic peritoneum lying higher up which are supplied by the plexus sacralis and which are irritated by traction. These parts of vaginal operation which are not made painless by parasacral anesthesia are, as a rule, of short duration and their beginning and ending can be determined accurately in advance. The use at such times of a short ethyl chloride or ether anesthesia satisfies both the patient and the operator. This is not necessary if the patient has been well prepared with narcotics, particularly veronal and scopolamine-morphine. The use of scopolamine "twilight sleep" should be omitted only when one desires to form an opinion as to the effectiveness of a particular method of local anesthesia, since when it is used it makes judgment on this point impossible. It remains to be determined whether the area made anesthetic by parasacral injection can be enlarged by still further injections through the vagina. Something may be expected from this only when both lateral walls of the pelvis are infiltrated at the highest point of attachment of the broad ligaments. For some time the author used such injections of various concentrations of novocaine-suprarenin solutions through the lateral vault of the vagina in the manner described by Ruge combined with parasacral anesthesia, but he has given them up because they were of no value in enlarging the area of anesthesia. Injections of the lateral wall of the pelvis through the vagina produces at best as good but no better anesthesia than does the parasacral injection. The latter is by far the simpler method and possesses in addition the advantages that the injections are not made in the field of operation itself, which cannot with certainty be made aseptic, but at some distance from it. The method of Ruge and Thalef, therefore, cannot come in competition with parasacral anesthesia. The combination of parasacral and paravertebral anesthesia for vaginal operations as recommended by Siegel and Frigyesi is unnecessary and the method requires too much detail for more extensive operations. Frigyesi who has used parasacral anesthesia extensively in vaginal operations recommended in cases where this is impossible after opening the anterior or posterior vaginal vault that the round ligaments and the infundibulo-pelvic ligaments be injected with a 0.5 per cent novocaine-suprarenin solution whereupon the ligaments and the adnexa become insensitive. For the great majority of vaginal operations parasacral

anesthesia alone or with the help of scopolamine or occasionally light short narcosis represents the best methods of producing anesthesia at the present time since it is simple in technic, therefore easy to learn, perfectly reliable, almost without failure and without danger. Parasacral anesthesia is also suitable for simple curettage of the uterus and for emptying the uterus after abortions, but the author believes it will be difficult for the physician to refrain from using narcosis in these short procedures. The advantage of local anesthesia becomes much more apparent in operations of greater magnitude. Concerning the use of local anesthesia in obstetrical operations the following may be mentioned: For suturing

FIG. 171.—Anesthesia of the introitus vaginæ, including the labia majora.

lacerations of the perineum the immediate infiltration of the parts is the simplest method, as already stated. Thaler, in a few cases, has emptied the pregnant uterus under local anesthesia with success. Bolag found that bilateral blocking of the nervus pudendus prevented the expulsion pains of labor while the contraction pains remained uninfluenced. Siegel reports 226 obstetrical operations of all kinds done paravertebrally combined with parasacral anesthesia. In 95.1 per cent of the cases the operations were completed without the help of narcosis. So far as the vaginal operations are concerned, the success is to be attributed to parasacral anesthesia. While the author cannot state from his own experience yet he believes that a significant future is near at hand for parasacral anesthesia

in obstetrical practice, since it permits painless dilatation and emptying of the uterus. Traugott used local anesthesia in 12 cases of abdominal Caesarean section. He infiltrated the abdominal wall in the line of incision. In most of the cases ethyl chloride stupor or complete narcosis had to be resorted to.

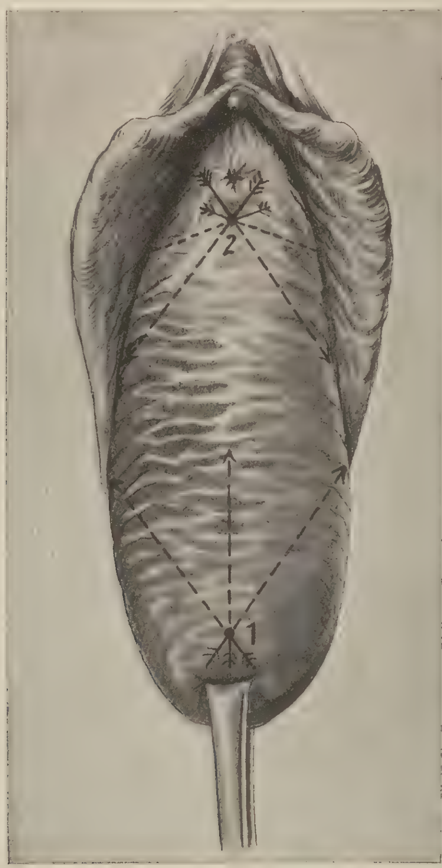

FIG. 172.—Anterior colporrhaphy.

OPERATIONS IN THE ANAL REGION.

Local anesthesia for operations on the anus is worthy of more consideration than it has received in the past, for such operations can easily be performed without general anesthesia. Reclus and Schleich (the former as early as 1889) have again and again called attention to the fact that the anal region is particularly suitable for performing operations under local anesthesia, and it was not without special reasons that Schleich selected an anal operation for demonstration at the German Congress of

Surgeons in 1894. To one who is unfamiliar with this subject there is something surprising in seeing the painlessness of a forced dilatation of the anus and the excision of hemorrhoids without a general anesthetic. It is, therefore, all the more remarkable that anal operations are still being performed under general or lumbar anesthesia.

Dilatation of the Anus; Operations for Hemorrhoids; Operations for Anal Fistulæ.—Before beginning operations of this kind it must be remembered that the bilateral blocking of the trunk of the pudic nerve will not be sufficient to produce anesthesia of the anus, neither will the

Fig. 173.—Circuminjection of anus and rectum.

filling of the ischiorectal fossa with a 0.5 per cent novocaine-suprarenin solution be sufficient; even though the latter procedure causes a more reliable blocking of the branches of the pudic and posterior femoral cutaneous nerves which supply the anus than is produced by the uncertain injection of the trunk of the pudic nerve.

The further innervation of the rectum and anus through the coccygeal plexus and pelvic nerve must also be taken into consideration. Laewen's sacral injection produces a splendid relaxation of the sphincter ani and anesthesia of the anal region. Unfortunately it is not reliable and a better method is in circuminjecting the anus. In some operations about the anus,

the anemia produced by the suprarenin is of great value, for example, in the Whitehead method of excision of hemorrhoids. The typical circum-injection of the anus, the principle of which was first described by Reclus, is performed in the following manner: Four points of entrance are marked in the region of but not too close to the anus, perhaps 2 to 3 finger-breadths distant from the anal orifice (Fig. 173). From these points a 0.5 per cent solution of novocaine-suprarenin is injected with a needle 10 cm. long. The needle is first inserted perpendicularly at one of the lateral points, parallel with the wall of the rectum, penetrating the sphincter and the

Fig. 174.—Position of needle for circuminjecting the rectum.

levator ani. The needle is partly withdrawn and again passed deeply to its full length, in a more oblique direction toward the anterior and posterior walls of the rectum. The direction taken by the needle is very well shown in Fig. 174. At least 5 cc of 0.5 per cent novocaine-suprarenin solution is continuously injected with each insertion of the needle. The same injection is made into the three other points marked, so that at least 60 cc of the solution would be used for the entire injection. On introducing the needle at the posterior point, care must be taken that it pass between the rectum and the coccyx and sacrum. The circuminjection of

the anus is made from one point to the other in two different layers, one injection into the sphincter and the other into the subcutaneous tissue (Fig. 172). For this 20 cc more of the solution will be used, making altogether 100 cc, and 125 cc in fat persons. These injections can be made without inserting the finger into the rectum. Occasionally, when the position of the needle seems doubtful, it may be controlled with the finger. Anyone who is inexperienced should make the deep injections with the aid of the guiding finger as shown in Fig. 175. In the deepest injections the point of the needle should be felt under the rectal wall, above the sphincter. In women the anterior injection is controlled through the vagina. If in anal fissure the finger cannot be introduced on account of intense pain, it is well to follow the advice of Reclus and previously make the mucous membrane insensitive by inserting cotton tampons soaked in

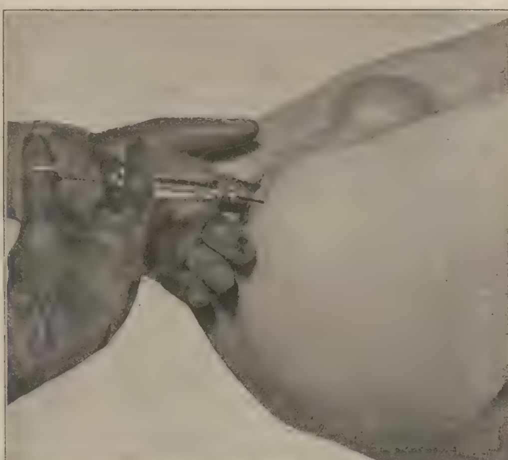

Fig. 175.—Para-anal injection under guidance of the finger.

an anesthetic (2 per cent alypin-suprarenin solution). An experienced person can dispense with this method. The sphincter relaxes in a very few minutes after the circuminjection and can be dilated, excised, or cauterized as much as desired.

In complicated cases of rectal fistula where the extent cannot be exactly estimated, it is advisable to proceed as in operations for hemorrhoids, and circuminject the entire anus, in which case the points of entrance should be so located that the fistulous tract is situated within the circuminjected area. In simple, direct fistula where the probe passes directly into the rectum and in which the inner opening can be felt, and dilatation of the sphincter is not necessary, a simpler method can be used. Three points of entrance are marked along the outer opening of the fistula (Fig. 176) and the needle is inserted into each of these points and from them continuous injection is made down to the mucous membrane of the rectum,

under the guidance of a finger, close to the inner opening, and finally a subcutaneous and submucous injection is made in the direction of the dotted line. Sometimes the outlet of the fistulous tract lies far from the anus, and it is almost impossible to determine the extent of the operative field. In such cases circuminjection is not applicable and sacral or parasacral conduction anesthesia is more suitable. The latter is also an excellent method of anesthesia for hemorrhoidal operations, but it lacks the advantage of the anemia produced by suprarenin, which is so valuable in the Whitehead operation for hemorrhoids. Periproctitic abscesses are best opened under ether or ethyl chloride anesthesia.

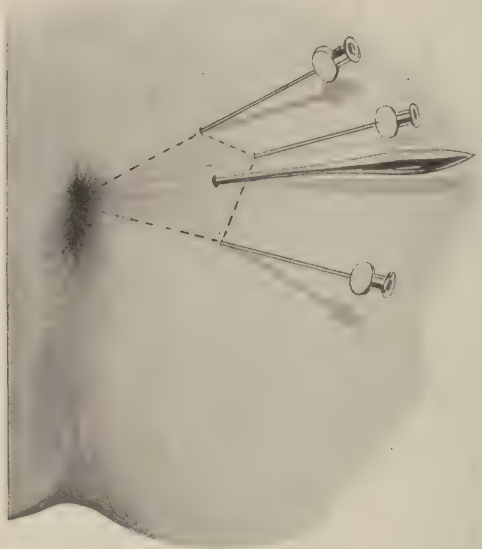

FIG. 176.—Technic of injection for simple rectal fistula.

Operations in Carcinoma of the Rectum.—Parasacral anesthesia has become the regular method of anesthesia in operations on the rectum for carcinoma. In 19 cases of removal of the anus and 6 cases of sacral resection of the carcinomatous rectum the anesthesia was complete, in 24 even when the sigmoid flexor had to be loosened high up. In only 1 case of resection in 1913 immediately after the introduction of the newer methods was it necessary to resort to narcosis. In sacral resection the tissues on the posterior side of the sacrum and the upper part of the skin incision must be infiltrated, since they are not supplied by the anterior sacral nerves. The usefulness of parasacral anesthesia in operations for rectal carcinoma has been confirmed by Schmerz.

CHAPTER XVI.

OPERATIONS ON THE EXTREMITIES.

THE USE OF LOCAL ANESTHESIA FOR THE REDUCTION OF FRACTURES AND DISLOCATIONS.

Local anesthesia can be used in various ways for fractures and dislocations of the extremities. Conduction anesthesia is suitable for these cases just as for other operations. Kulenkampff's plexus anesthesia is of the greatest importance in this connection, because it brings about in a simple manner such complete motor and sensory paralysis of the arm and the shoulder muscles that a more favorable condition cannot be imagined. Another method is the direct injection of an anesthetic between the fractured ends or into the dislocated joint as recommended by Lerda and Quénu. As early as 1885, Conway attempted to produce anesthesia in 3 cases of fracture of the radius by injecting cocaine solutions between the broken ends of the bone. Furthermore, Reclus relates 1 case of fracture of the tibia in which he injected a cocaine solution at the point of fracture, in order to facilitate the transportation of the patient. He states that the fracture immediately became painless. There are no other case reports on this subject in the older literature. The first comprehensive reports were made in 1907 and 1908 by Lerda and Quénu, the former reporting 30 and the latter 15 fractures in different parts of the body which were painlessly replaced after injections of cocaine.

After establishing the diagnosis, injections of an anesthetic solution are made from various points and in different directions toward the ends of the fracture. If there is a marked dislocation of the broken ends, particularly in the long axis of the bone, injection must be made at each end of the broken bone. In limbs having two bones each fracture must be treated separately. In joint fractures, additional injections must be made into the joint.

Lerda and Quénu used a 0.5 per cent cocaine solution; one added suprarenin, the other omitted it. Conway increased the effect of the cocaine by ligating the extremity. We now use a 1 per cent novocaine-suprarenin solution. The points of entrance are previously prepared by painting with iodine. The result of this injection is very surprising, as almost immediately after the injection the pain subsides, and a few minutes later the fracture becomes entirely insensitive. The muscles relax as in general anesthesia.

Conway was the first to call attention to the use of intra-articular injections for dislocations (replacements of a dislocated elbow). In 1909, Quénu reported 5 cases of luxation which were painlessly replaced in this

manner (2 shoulder dislocations, 1 elbow, and 1 thumb luxation, and 1 ischiatic dislocation of the hip). The injection technic is very simple. The anesthetic (1 per cent novocaine-suprarenin solution) is injected both at the proximal and distal ends of the dislocated bones. Shortly after the injection the limb which was rigidly fixed becomes movable and painless and the muscles relax. Occasionally active movements and pressure on certain spots, the latter corresponding to the muscular attachments, remain painful. For such cases Quénu advises that more of the anesthetic be injected at the painful spot.

The following table shows the author's experience with local anesthesia in 51 simple fractures and luxations:

	Plexus anesthesia.	Other conduction anesthesia.	Local injections.
Typical fracture of radius	1	..	3
Fracture of forearm	7	..	1
Dislocation of elbow	..	..	1
Supracondyloid fracture of upper arm	4	..	1
Dislocations of shoulder	10	..	5
Dislocations of the foot	..	2	..
Fracture of ankle	..	3	7
Fracture of leg	..	1	1
Posterior dislocation of tibia	..	..	2
Dislocation of hip-joint	..	..	2
	22	6	23

In 23 cases local injections were made and only in 1 case of fracture of the tibia did they prove unsuccessful. In all other cases there was complete anesthesia, and the fractures were easily and painlessly reduced.

In fracture of the radius 10 cc novocaine-suprarenin solution were injected both from the extensor and radial side to the seat of fracture and some into the wrist-joint. In cases of fracture of both bones of the forearm 10 cc were injected into each point of fracture. In dislocations of the elbow an injection of 5 cc was made from behind through the triceps, and to the upper end of the joint of the forearm, and also freely around the lower end of the humerus. In a case of supracondyloid fracture of the upper arm, with dislocation, 20 cc were injected from behind in various directions about the seat of fracture and into the elbow-joint.

In 5 cases of forward dislocation of the shoulder 10 cc were injected through the deltoid muscle from without into the joint cavity, and the same quantity was injected around the luxated head of the humerus. In 7 fractures of the ankle, 15 cc were injected around the fractured fibula at the internal malleolus and into the ankle-joint.

In 2 cases of posterior dislocation of the tibia, 35 to 40 cc were injected from before and from both sides to the joint ends. The intra-articular injections for dislocation of the femur mentioned by Quénu are most interesting. One of 2 cases of this character, a recent anterior dislocation of the hip in a very strong miner, about forty-five years of age, was performed under this method as follows: From two points in the gluteal region 25 cc of a 1 per cent novocaine-suprarenin solution were injected

with a long needle to the head of the femur, which could be palpated and felt with the needle, and 20 cc of the solution into the joint cavity. The dislocated head of the femur cannot be used as a landmark for inserting the needle into the joint cavity owing to its changed relative position to the cavity. The pelvic bone must be used as a guide. A point close behind the anterior-superior spine of the ilium (Fig. 177) was selected for the entrance of the needle which was 10 cm. long, holding a bony pelvis next to the patient as a guide. The point of the needle was passed along the bone and immediately into the joint cavity, from which bloody synovial fluid was removed. Almost immediately after the injection the leg which was rigid before became movable and after ten minutes was easily

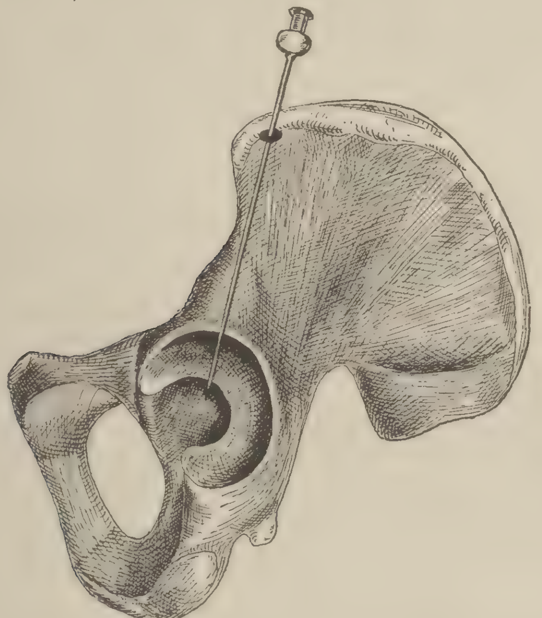

FIG. 177.—Injection into the hip-joint for dislocation.

replaced. The patient felt no pain in his hip, but later complained of the firm grip of the persons who were replacing the bone. The other case was an obturator dislocation of thirty-six hours' duration in a strong, stable boy aged seventeen years. Again 25 cc of the solution were injected into the joint cavity, 25 cc around the head of the femur, which could be felt under the pubic bone, and 10 cc more into a spot on the outside which had remained very sensitive. Ten minutes after the first and five minutes after the second injection the bone was easily and painlessly replaced. No bad results have been reported from the use of local anesthesia in fractures and dislocations; everything points to its surprising advantages. The only remote danger in using the local injections for fractures and

dislocations is the possibility of infection. Such a danger is so improbable at the present time that surgeons daily inject into the body large quantities of such solutions, and therefore there is no reason why they should not be also injected between fractured ends and into the joints.

There is one precaution which must always be observed in making these local injections, that is, the points of entrance should never be placed where there is an abrasion of the skin, or where it is crushed, thinned, or soiled. In such cases the local injections are best supplanted by the plexus anesthesia of Kulenkampff, which is so serviceable in dislocations of the shoulder. A shoulder dislocation of four weeks' standing was replaced with ease under plexus anesthesia.

Local injections are specially recommended for fractures of the lower extremity. Lerda and Quénu also used them frequently for this purpose. The advantages derived from the use of local anesthesia in the treatment of fractures are so evident that they only need be mentioned.

It is a decided technical advantage to be able to make cases of elbow and forearm fracture painless without a general anesthetic, and then to be able to examine the patient under the roentgen screen and leisurely decide upon the best method for replacing the limb and the best position in which to place it. The annoying and sometimes dangerous excitability of the anesthetized patient is avoided and bandages are more easily applied.

Dislocations are much more easily replaced than when patients have had general anesthesia. If plexus anesthesia is used, this fact is readily explained by the more complete relaxation of the muscles. Intra-articular injections decidedly facilitate the replacement of dislocations. Mention should be made of the communication of Payr, who filled the luxated joint with 80 to 100 cc of 0.5 per cent novocaine-suprarenin solution in order to distend the capsule and at the same time prepare a way for the dislocated bone.

OPERATIONS ON THE UPPER EXTREMITY.

The Sensory Innervation.—The brachial plexus supplies the entire sensory innervation of the arm as far as the shoulder-joint, and merges into a thin nerve trunk after leaving the opening in the scalenus muscle. In the axilla the upper intercostal nerves supply part of the sensory innervation, and one of them, the medial brachial cutaneous, supplies also a part of the skin of the upper arm. On the other hand, the skin of the shoulders is innervated from the cervical plexus by the supraclavicular nerves. Fig. 178 shows the sensory nerves of the upper extremity as they emerge from the fascia under the skin and their peripheral distribution. It is well to compare this with the scheme of Fig. 184 (page 363).

The details of the innervation will be considered and described only so far as they are concerned in the technic of the anesthesia. Rost has made an extensive investigation of the frequent variations in the points of emergence of the cutaneous nerves through the fascia.

Anesthesia of the Brachial Plexus.—Crile's method (page 160) of interrupting the brachial plexus, after exposing it just above the clavicle, has the disadvantage of all such procedures, and therefore has not become

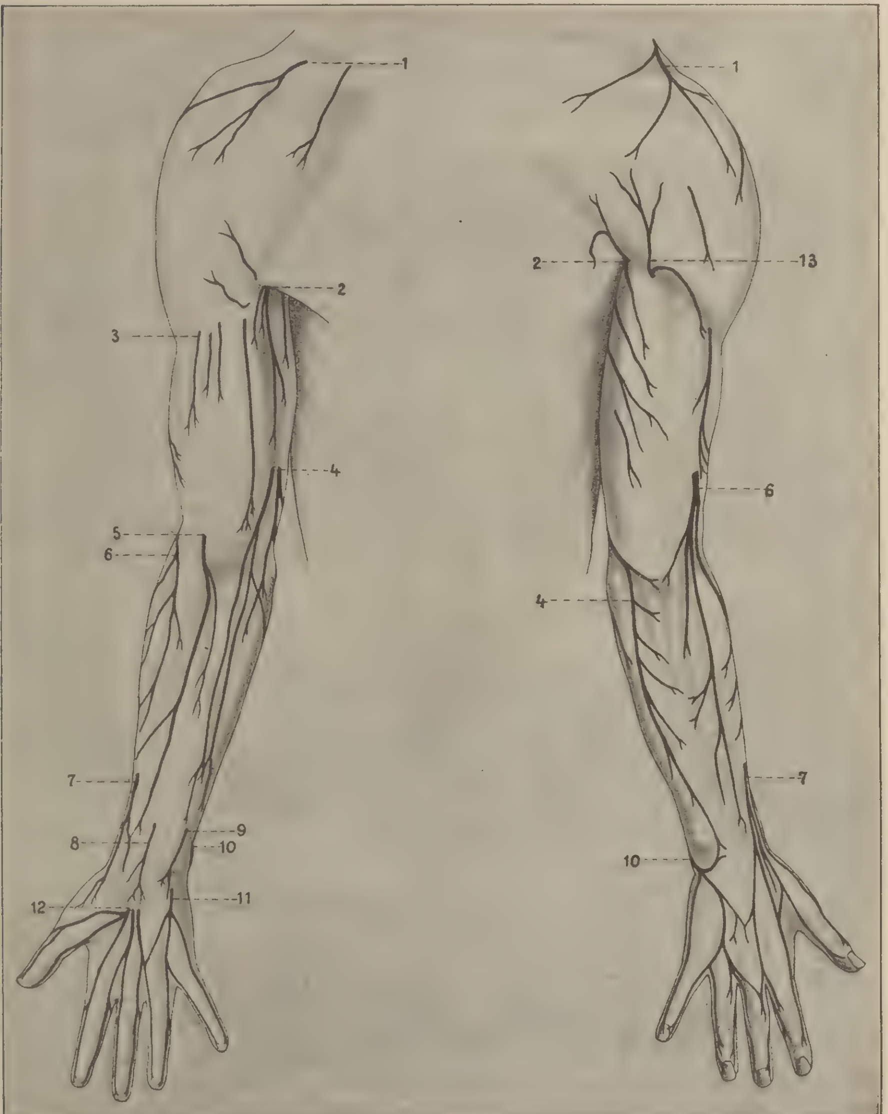

Fig. 178.—Sensory innervation of the upper extremity. 1, supraclavicular; 2, medial brachial cutaneous; 3, anterior brachial cutaneous; 4, medialanti brachial cutaneous; 5, lateral antibrachial cutaneous; 6, dorsal antibrachial cutaneous; 7, superficial radial; 8, palmar branch of median nerve; 9, palmar branch of ulnar nerve; 10, dorsal branch of ulnar nerve; 11, ulnar nerve; 12, median nerve; 13, lateral brachial cutaneous.

popular. Hirschel was the first author who was able to report upon the possibility of anesthetizing the entire arm (which was an impossibility before the introduction of suprarenin) by making the injection to the plexus through the skin.

He selected the axilla for his point of entrance. As high up in the axilla as possible a pad is bound to the thorax by two elastic bands in order to obtain a congestion of the vessels for the purpose of slowing the process of absorption. The arm is strongly abducted, the axillary artery fixed with the fingers of one hand and the needle inserted as far up under the pectoralis major as possible, in the direction of the long axis of the arm. Injection must be made as the needle advances, which will cause the vessels to slip away from the needle and thus prevent injury.

Several syringefuls of the solution are injected around the median nerve above and around the ulnar anteriorly. One further injection is still necessary underneath the artery, about the insertion of the latissimus dorsi, where the radial nerve is encountered. In this manner the artery is circuminjected and with a little caution any lesion to the artery or vein can be avoided. Hirschel first reported 3 injections successfully carried out in this way, and later reported 25 cases, and at the same time mentioned the fact that he considered the constriction of the vessels unnecessary; 30 to 40 cc of 2 per cent novocaine-suprarenin solution are sufficient for this anesthesia. Soon after Hirschel's first report, Kulenkampff also reported 25 cases of successful anesthesia of the brachial plexus. For blocking he chose the spot where the plexus lies on the first rib, lateral to the subclavian artery, and made the first experiments upon himself. The location of the plexus can be very definitely determined, being bounded on the inner side by the subclavian artery whose pulsations can be felt below by the first rib and anteriorly by the clavicle. The subclavian vein lies to the outer side.

The daily use of the plexus anesthesia, according to Kulenkampff, has proved this procedure to be a typical, harmless, very simple, and, at the same time, reliable method of anesthesia. It is suitable for all operations on the upper extremities and especially for the replacement of shoulder dislocation, for which purpose it is undoubtedly far superior to Quénu's method mentioned above. It has made general anesthesia almost superfluous for operations on the upper extremity. Kulenkampff has recently given an accurate account of the experience gained in his first 160 cases. The anatomical relations of the point of injection are shown in Kulenkampff's diagram (Figs. 179 to 181). Fig. 179 shows the position of the first rib, when viewing the supraclavicular region from the side. It should be noted how it apparently rises perpendicularly above and behind the clavicle. This is of importance, as it represents the lowest point to which the properly guided needle can penetrate. The operator does not experience that uncomfortable feeling of inserting the needle to a great depth, without feeling any resistance and not knowing the location of the point of the needle. The first rib crosses the clavicle at about its center, which is the spot where the most important wheal must be placed. Medi-

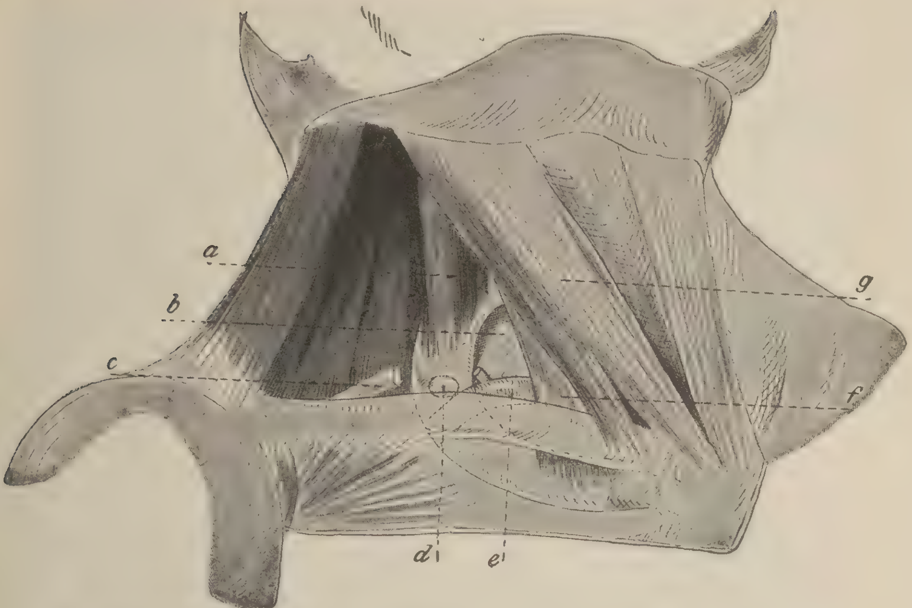

FIG. 179.—Relation of first rib and subclavian artery to the clavicle. (Kulenkampff.) *a*, scalenus medius muscle; *b*, apex of lung; *c*, omohyoid muscle; *d*, wheal; *e*, subclavian artery and its branch, the transverse colli; *f*, scalenus anticus muscle; *g*, sternocleidomastoid muscle.

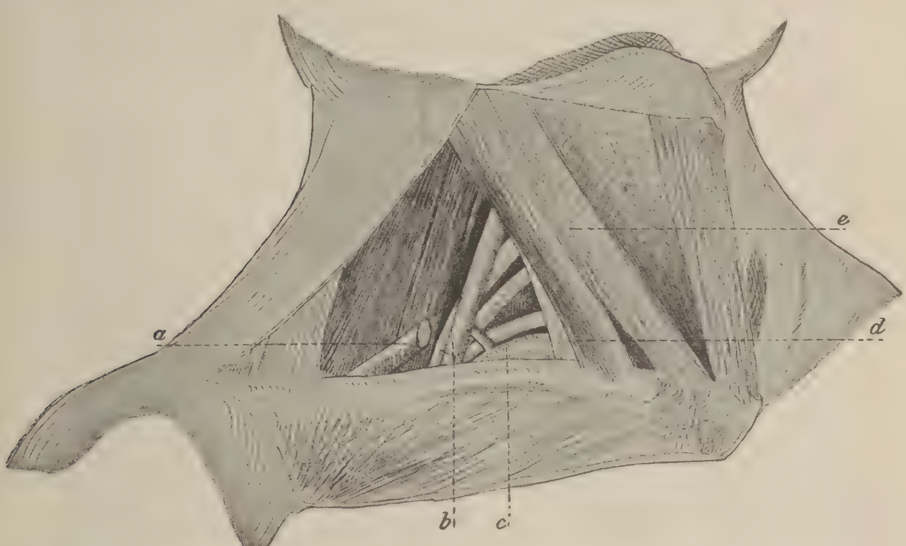

FIG. 180.—Relation of the brachial plexus to clavicle and subclavian artery. (Kulenkampff.) *a*, omohyoid muscle; *b*, brachial plexus (partly schematic); *c*, subclavian artery with the transverse colli; *d*, scalenus anticus muscle; *e*, sternocleidomastoid muscle.

ally, the arch of the subclavian artery is also recognized, as it extends above the clavicle and above this the pleural arch makes its appearance, which is otherwise covered by the brachial plexus. Furthermore, the scalenus anticus is recognized on the outer edge of the sternocleidomastoid muscle and the obliquely ascending omohyoid is seen to the outer side of the first rib. It is cut off here, in order to show as plainly as possible the direction taken by the rib. Fig. 180 shows the relative positions as they appear after the removal of the skin, superficial and deep fascia. The transversus colli artery is seen, as it usually passes in the midst of the closely overlapping nerve trunks. Fig 181 shows how the needle should be introduced in order to reach the first rib. Depending upon the angle at which the cervical vertebræ approach the sternum, a projection of the axis of the needle would strike the second to fourth spinous process of the dorsal vertebra.

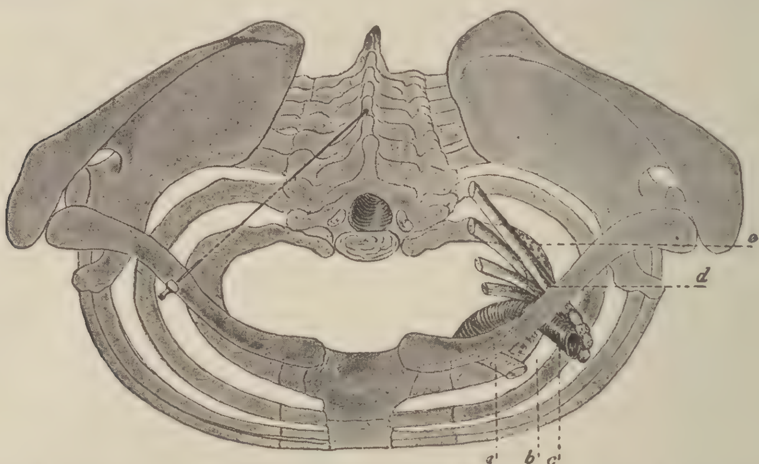

FIG. 181.—Bony thorax from above (Kulenkampff) showing the relation of the plexus and subclavian artery to the clavicle on one side and the position of the needle on the other. *a*, subclavian vein; *b*, attachment of the scalenus anticus muscle; *c*, subclavian artery; *d*, brachial plexus surrounding the artery in a sickle-shaped manner; *e*, attachment of the scalenus medius muscle.

On the opposite side the plexus, artery, attachment of the scalenus muscle, and the vein are shown particularly with reference to the sickle shape of the cross-section. It also shows how the artery is surrounded by nerve trunks immediately under the clavicle. It can be readily seen that a needle inserted close to the artery must pass between the nerve trunks, and that if it is properly inserted it will, without fail, transmit the pulsation of the artery. The diagram shows the narrow slit of the scalenus muscle somewhat more plainly than Figs. 179 and 180.

The technic of the injection is as follows: It is advisable whenever possible to have the patient in the sitting posture while being anesthetized (Fig. 182). The patient needs no previously administered opiate, but he should certainly be informed of the paresthesia, which radiates to the

fingers and which will arise when the needle penetrates to the plexus, and he should be instructed to state when he feels these sensations. This is the only way to positively determine when the needle has reached the right spot. The next step is to palpate the subclavian artery, which is done by making gentle pressure with the finger. In many cases the pulsation is visible more often to the right than to the left, which may be explained by varying anatomical relations. A wheal is placed directly outward from the spot where the artery disappears behind the edge of the clavicle. The spot almost without exception will correspond to the middle of the clavicle. At this same point, as a rule, a downward prolongation of the external jugular vein, which is usually visible, also crosses the clavicle. Here we insert a fine needle, 4 to 6 cm. long, without syringe, in the direction which it should take to strike the spinous process of the second or third

Fig. 182.—Plexus anesthesia. (After Kulenkampff.)

dorsal vertebræ (Fig. 181). The plexus lies rather close to and under the fascia. As soon as the needle touches it, radiating paresthetic sensations are complained of in the fingers supplied by the median nerve which lies superficially, and of the radial nerve which lies deeper and posterior to the median nerve. If at a depth of 1 to 3 cm. the first rib is felt, it indicates that the plexus must lie more superficially. If paresthesia is not obtained at once, it must be sought by slightly changing the position of the needle. Very often from an unnecessary anxiety about the subclavian artery the needle is inserted too far outward. If blood flows from the needle, its direction must be changed. As soon as the paresthesia occurs, attach the syringe to the needle and inject 10 cc of a 2 per cent novocaine-suprarenin solution. If paresthesia evidences itself in the region supplied by the median nerve, a part of the solution should be injected a few millimeters deeper. Finally, 10 cc more are injected so as to be distributed in the

immediate surroundings, the direction of the needle being very slightly changed during this injection.

The operator should not make the injection before the paresthesia occurs. If there is a pronounced paresthesia of the median as well as of the radial nerve, it indicates that a complete sensory and motor paralysis of the arm will occur after one to three minutes. It is usually necessary to wait ten to fifteen minutes, but if after this length of time the paralysis is not complete, it will be advisable to make another injection of 5 to 10 cc of 4 per cent novocaine-suprarenin solution. Paresthesia will not be felt after this latter injection and results are more or less uncertain.

Very soon after the injection the upper arm can be constricted to arrest hemorrhage without any discomfort to the patient. For this

Fig. 183.—Location of puncture of the brachial plexus.

purpose use Perthe's compressor. Constriction is usually necessary, because, after blocking the brachial plexus, the arm becomes more or less hyperemic as in Haidenhain's experiment. The evident contrary action of suprarenin in not causing contraction of the subclavian artery is similar to the observations made on extremities after section of the nerves.

The number of failures which will result will depend upon the experience of the surgeon. Kulenkampff reports that in 100 cases anesthetized by eight different surgeons, in 4 cases it was found impossible to cause paresthesia and, therefore, the injections were ineffective. In 19 other cases some areas supplied by certain nerves were not completely blocked, but in most cases the operations could be performed.

The extent of the anesthesia following the injection is shown in Fig. 184. There is always a motor paralysis of the axillary nerve. It is, therefore,

rather surprising that the skin which is innervated by the sensory part of the axillary nerve, as is taught in text-books on anatomy, is never rendered

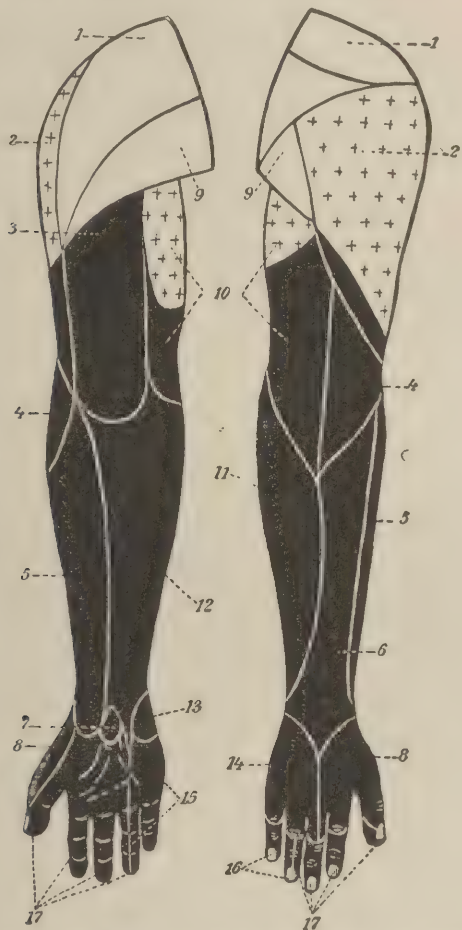

FIG. 184.—Sensory tracts of upper arm (after Toldt) and the effect of blocking the brachial plexus. (After Kulenkampff.) ■ anesthesia; + + hyperesthesia or not paralyzed; □ not paralyzed: 1, supraclavicular nerves; 2, lateral brachial cutaneous (derived from the axillary nerve); 3, cutaneous branch of the anterior brachial (derived from the medial antibrachial cutaneous); 4, posterior brachial cutaneous (derived from the radial); 5, lateral antibrachial cutaneous (derived from the musculocutaneous); 6, dorsal antibrachial cutaneous (derived from the radial); 7, medial palmar branch; 8, superficial branch of the radial; 9, lateral cutaneous branch (derived from the intercostal); 10, medial brachial cutaneous; 11, ulnar branch of the medial antibrachial cutaneous; 12, volar branch of the medial antibrachial cutaneous; 13, palmar cutaneous branch of the ulnar; 14, dorsal branch of the ulnar; 15, superficial branch of the ulnar; 16, digital volar (derived from the ulnar); 17, digital volar (derived from the median).

insensitive but is either hypesthetic or not affected at all. From this observation it is probable that innervation of these parts must take place

from other nerves, probably the supraclavicular. The anesthesia produced will last from one and a half to three hours. In 160 cases Kulenkampff observed no injury at the point of injection and no postoperative pains. It is possible to puncture the subclavian artery during this injection but so far this accident has been free from danger. In plexus anesthesia, which in a short time has been used quite extensively, the following secondary effects have been observed.

1. *Sympathetic Paralysis on the Same Side* (Kulenkampff).—It makes its appearance quite frequently and manifest itself by a narrowing of the space between the eyelids and by a contraction of the pupil and a hyperemia of the conjunctiva and one-half of the face. At times there is an irritation of the sympathetic with a dilatation of the pupil. Both symptoms are of short duration and have no further significance.

2. *Paralysis of the Phrenic Nerve.*—This occurrence, the possibility of which Kulenkampff had already pointed out, was proven roentgenologically by Sivers. Haertel and Keppler have examined roentgenologically a large number of cases after plexus blocking and have demonstrated that paralysis of the phrenic nerve on the same side is a regular but temporary accompaniment of Kulenkampff injection. It shows itself in the roentgen picture by a suspension, diminished excursion or paradoxical movement of the corresponding half of the diaphragm and which disappears usually in a few hours and presents no subjective symptoms. Haertel and Keppler warn against bilateral plexus blocking, since the possibility of the paralysis of the phrenic lasting so long as to be harmful cannot be denied.

3. *Injury of the Pleura.*—Haertel and Keppler describe 2 notorious cases of injury of the pleura with the needle in one of which air was demonstrated in the pleural cavity and in the other emphysema of the skin developed. Furthermore in a number of cases first mentioned by Heile usually very soon after the injection and in fact before the solution had been injected (Stein) symptoms of irritation of the pleura had made their appearance such as pain in the chest, pain in the corresponding shoulder and dyspnea. These symptoms have usually lasted until the next day without leaving behind any bad results. They are not due, as Sievers claims, to a functional disturbance of the phrenic nerve, but to an injury to the pleura or to a hemorrhage into the pleural cavity (Heile). Similar symptoms have been seen following injections in the neck for thyroidectomy in 1 case of thyroidectomy under narcosis (Brunner) and in intercostal injections on the chest (Kulenkampff). The author recently saw such symptoms in a case of intercostal injection for operating on a kidney, but he has not seen them in plexus blocking.

Schepelmann has observed more or less severe respiratory disturbances 4 times in 300 cases of plexus anesthesia after Kulenkampff and 1 case complicated with severe pneumothorax. Capelle saw a pneumothorax with emphysema of the skin make its appearance after a puncture of the plexus which caused the death of the patient. There is always reason, therefore, to fear puncture of the apex of the lung and every possible precaution should be taken to prevent this accident. The endangered

point of the lung lies internally to the first rib. Injury to the pleura may best be prevented by passing the needle down to the first rib a little to the outer side of the middle of the clavicle. The length to which the needle has been introduced is then marked by a piece of cork or a movable slide after Haertel, and then when injecting the plexus not to introduce the needle farther than the point indicated. The plexus lies more superficially than the first rib. On account of the misfortune which befell Capelle, he prefers to inject the plexus after the method of Hirschel. He recommends as the place of introduction a point on the sulcus bicipitalis internalis which lies close above the attachment of the tendon of the pectoralis major muscle. After giving off the axillary nerve, the nerve trunks lie close to the artery and it is only necessary, therefore, to inject 20 to 30 cc of a 2 per cent novocaine-suprarenin solution around and about the easily palpable artery. After a waiting period (thirty minutes or more) anesthesia is obtained extending as high as the lower third of the upper arm. Babitzki has pointed out that the brachial plexus can be punctured very easily below the clavicle at the well-defined point where the inner border of the second rib crosses the clavicle. The danger of injuring the pleura may be avoided with reasonable certainty even by the inexperienced by following the method of Mulley, in which the plexus is punctured higher up in the neck. The point of puncture lies 3 finger-breadths above the middle of the clavicle and $\frac{1}{2}$ cm. posterior to the apex of a triangle whose base is formed by the clavicle and its sides by the posterior border of the sternocleidomastoid muscle and the anterior border of the posterior muscles of the neck. [The apex of this triangle is not a clearly defined point and, therefore, not easily recognizable.—Ed.] The needle is introduced perpendicularly until paresthesia is experienced by the patient. With a little practice the plexus can be reached at this point with as much certainty as at the first rib. Experience, however, must show whether or not the closer proximity of the injection to the vertebral column involved other complications.

4. *Injury to the Arm Nerves.*—Borchers, Hirschler, Haertel and Keppler have reported such injuries. In Borchers' case a paralysis of the radial, ulnar and median nerves, lasting several weeks, followed an operation under plexus anesthesia. During the operation, however, a constrictor had been applied to the upper arm. Hirschler observed a paralysis of the flexor of the index finger follow the reposition of an axillary dislocation of the shoulder under plexus anesthesia. In a second case an area of anesthesia was observed on the upper arm in the region of the distribution of the musculocutaneous nerve following the repair of an incised wound of the soft parts of the forearm. In a third case anesthesia of the little finger was observed after reposition of a fracture of the forearm. Haertel and Keppler report a case of fracture of the upper arm with paralysis of the radial nerve. The nerve was cut down on under plexus anesthesia, following which there developed a gradually increasing disturbance of the ulnar and median nerves. Haertel and Keppler themselves point out that in none of these cases is the evidence conclusive that the nerve injury

was the result of the plexus anesthesia. In the following case, however, they consider the evidence conclusive. A fracture of the forearm in a woman was reduced in the usual way under plexus anesthesia. After nine days in a Schaede's splint there developed a complete paralysis of the radial nerve. The other nerves of the arm were involved in the process. At the end of six months the disturbance was perceptibly better but it had not entirely disappeared.

Damage to the nerves as the result of injections may arise through injury to the nerves with the needle, through hemorrhage into the nerve sheaf or through the effect of the fluid. We have hitherto assumed that pure isotonic novocaine-suprarenin solutions caused no lasting damage to the nerve substance, and up to the present time our experience has justified this assumption. In endoneural injections—which often applies to plexus anesthesia—particular importance is to be placed on the purity and isotonicity of the solution, for it is well known how sensitive nerve substance is to disturbance in osmotic equilibrium and particularly to swelling. Owing to the rarity of such cases as those described above we are of the opinion that too little is known to permit much to be said on the subject.

The duration of plexus anesthesia is from one and a half to three hours. Such secondary effect as have occurred in blocking a cervical plexus have not been observed in blocking the brachial plexus.

The indications for plexus anesthesia are found in all bloody and bloodless surgical operations on the arm except those which can be handled more easily by local injections. In the author's experience the majority of the operations done under plexus anesthesia are for severe injuries to the hand and for infections of the hand and forearm, to which may be added amputations. exarticulations and resections of the upper extremity and for the reposition of fractured bones and dislocations. Exarticulation at the shoulder and resection of the shoulder joint can be performed painlessly by injecting a 0.5 per cent novocaine-suprarenin solution in the subcutaneous tissues about the root of the extremity and transversely across the axilla and over the shoulder. The end branches of the supraclavicular and the intercostal nerves are thus blocked. This method is of value in the reposition of fractures with the aid of the roentgen screen.

Anesthesia of a Finger, According to Oberst.—This anesthesia is based upon the fact that the nerves supplying all the fingers lie in the subcutaneous connective tissue of the first phalanx (page 155). Fig. 185 shows schematically a cross-section of the first phalanx. The main nerve trunks are indicated by black dots. The most important nerves lie toward the volar surface, close to the flexor tendons. These nerves divide high up into branches which extend to the dorsal side, innervating the extensor surface of the second and third phalanges. Under the skin of the extensor surface are two fine nerve branches which, as a rule, do not extend beyond the first phalanx.

The anesthetic must be injected into the region of these nerve trunks. For this, two points of entrance will be necessary, which should be situated

on the side of the finger more toward the extensor surface (Fig. 185, 1, 2) where the skin is least sensitive. The injection is begun by making a wheal at one of the points of entrance with a very fine sharp needle. The

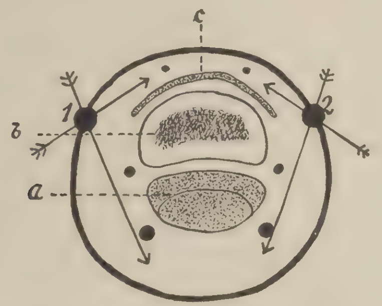

FIG. 185.—Anesthesia of Oberst. Schematic cross-section of the base of a finger. 1 and 2, points for injection. *a*, flexor tendon; *b*, bone; *c*, extensor tendon. The nerves are indicated by black dots. The arrows indicate the direction of the needle.

FIG. 186.—Injection of the finger, according to Oberst.

needle is then inserted transversely to the long axis of the finger in Fig. 185, 1 and 2; the position of the needle is indicated by arrows injecting the solution under the skin of the flexor surface. The needle is now removed and again inserted into the same spot, now insensitive, in order

to inject beneath the skin of the extensor side. The solution, which should saturate the subcutaneous connective tissue in a circular manner, ought to be so distributed that the flexor side receives a little more than the extensor side. Inject 2 to 2.5 cc of a 2 per cent novocaine-suprarenin solution. It is necessary to wait until the tip of the finger has become insensitive to the prick of a needle, which usually occurs in five minutes. The finger is then totally insensitive and any operation, either bloody or bloodless, can be performed (reduction of luxations). This method is suitable for felons when they do not extend beyond the middle phalanx. Oberst's method of ligating the finger before making the injection of the anesthetizing solution is unnecessary owing to the addition of the suprarenin. The finger arteries are end arteries, therefore the injection of suprarenin into the finger must be made cautiously. Even if the subcutaneous connective tissue of the finger is filled with a dilute suprarenin solution, all its arteries will contract, and it is with difficulty that the suprarenin is eliminated. The condition is similar to that of a pediculated skin flap (Fig. 187) or the prepuce (page 329).

This is undoubtedly responsible for the disturbances and secondary pains, which are frequently noticed after finger anesthesia. These disturbances are not observed when the injection is carried out according to the Oberst method—namely, ligating the finger before injecting 1 to 2 cc of 0.5 per cent cocaine solution. They can also be avoided if the injection is made as close as possible to the base of the finger, where the blood supply is more abundant, and if the subcutaneous connective tissue is not too tensely infiltrated with an injection of too large a quantity, as 10 cc of 0.5 per cent novocaine-suprarenin solution. It is therefore preferable to use a small quantity of 2 per cent novocaine-suprarenin solution in the manner described. Unilateral injections made only to the flexor or only to the extensor surface are seldom used. Small furuncles on the extensor side of the first phalanx can easily be made insensitive by a fork-shaped injection (Fig. 185) on the index finger.[1]

Anesthesia of One Finger and the Surrounding Part of the Hand.—The introduction of suprarenin has made it possible to work out several methods of injection which will include the palm and which would otherwise be possible only by ligating the arm, a process which takes up much time and is very disagreeable to the patient, and, therefore, could never become popular.

In order to make one finger with the neighboring part of the palm or back of the hand insensitive, two points of entrance are marked on the back of the interdigital folds (Fig. 187, 1 and 2 or 2 and 3).

For the thumb and fifth finger the points of entrance are placed respectively on the outer or inner edge of the hand. From these points a 0.5 or 1 per cent novocaine-suprarenin solution is freely injected subcutane-

[1] Inasmuch as the fingers and toes are supplied by end arteries, I would suggest that novocaine be used without the addition of suprarenin, and that the circulation be interrupted by a narrow elastic band in order to avoid any evil effects resulting from the prolonged constriction of the vessels from suprarenin.

ously in a direction toward the points *a* and *d* in the palm and *b* or *c* on the back of the hand. Fig. 188 demonstrates the direction of the needle for injections of the palm from one of the interdigital folds. Points of

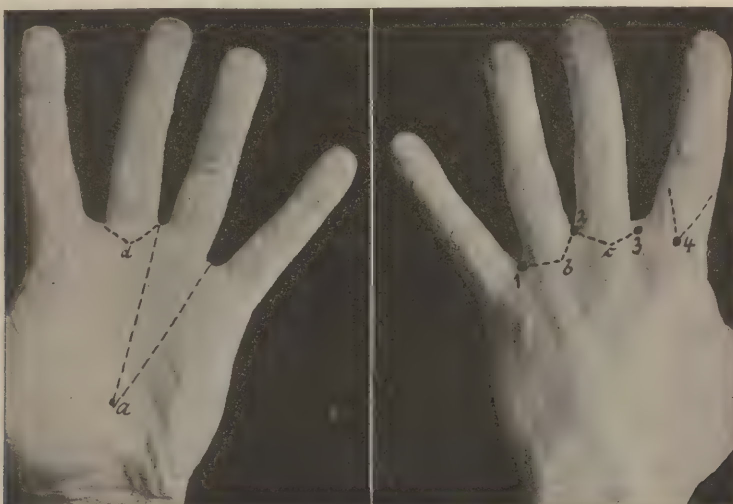

Fig. 187.—Fork-shaped injection of the index finger. Anesthesia of a finger with portions of palmar and dorsal surface. (Third and fourth fingers.) 1 to 4 indicate points for injection.

entrance should never be placed in the palm, as the skin is too hard and sensitive. The operation should not be begun until the anesthesia has extended to the tip of the finger under consideration. A free infiltration

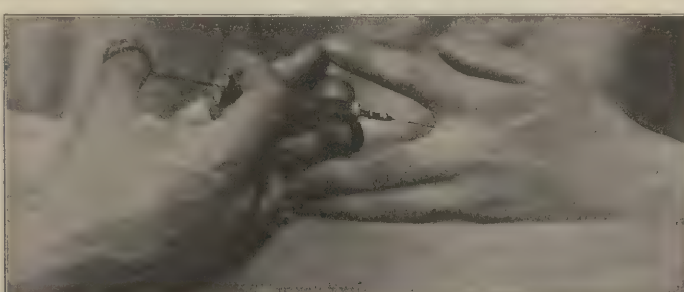

Fig. 188.—Method of introducing a needle through an interdigital fold to the hand.

of the solution mentioned can be made without the precaution which is usually necessary for injection of the fingers.

Disarticulation of the Middle Finger at the Basal Phalanx. Operations on the Third Metacarpal Bone.—Four points of entrance must be marked

(Figs. 189 and 190); two of them in the interdigital fold, two on the back of the hand to the right and left of the third metacarpal bone and over the

Fig. 189

Fig. 190

Figs. 189 and 190.—Disarticulation of the middle finger and thumb at the base. Operations upon a metacarpal bone.

spaces between the bones. Two injections are made from points 3 and 4. Fig. 191 shows a cross-section through the palm and indicates the direction

which the needle must take. For this injection the operator places the tip of his left index finger into the patient's palm and inserts the needle

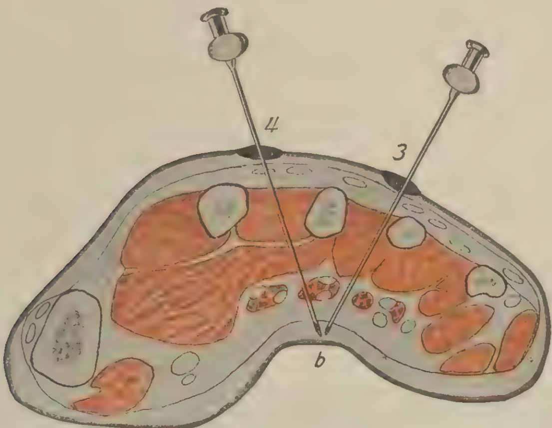

Fig. 191.—Cross-section through the middle of the hand. Direction of the needle in the interosseous spaces. 3, 4, and *b* correspond to similar points of Figs. 189 and 190.

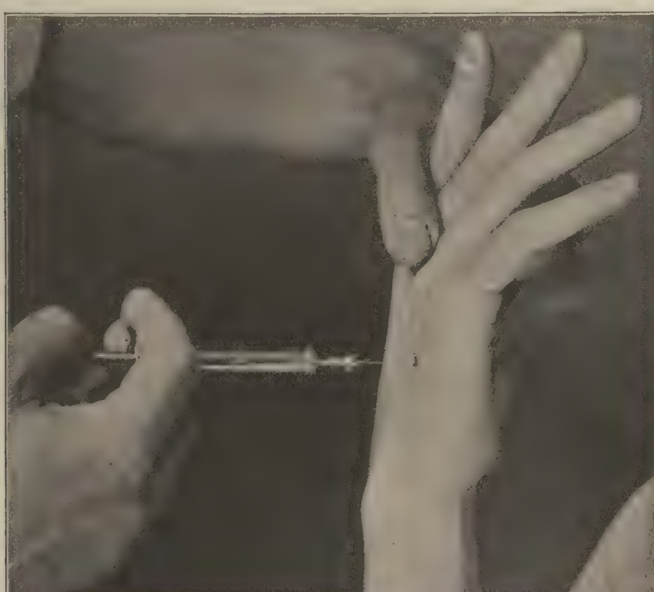

Fig. 192.—Method of injecting an interosseous space.

at points 3 and 4, making constant injection directly through the space which lies between the bones until the point is felt beneath the skin of the palm at point (*b*). Fig. 192 demonstrates the technic of this injection.

For each of the two injections 5 cc of 0.5 per cent novocaine-suprarenin solution will be required. These injections are followed by the infiltration of the subcutaneous connective tissue from points 1 and 2 toward point *b* in the palm, and on the back of the hand toward points 3 and 4. Finally, points 3 and 4 are joined by a subcutaneous injection. Altogether 30 to 40 cc of 0.5 per cent novocaine-suprarenin solution are required. The anesthesia is completed when the tip of the middle finger has become insensitive. The finger can now be disarticulated, with or without removing its metacarpal bone. It is unnecessary to constrict the arm. This same method is used for operation on the third metacarpal bone.

The Disarticulation of the Thumb at the Basal Phalanx. Operations on the First Metacarpal Bone (Fig. 187).—The injection between the bones is begun from point 6 and the needle is inserted until felt under the skin of the palm at point *a*. On account of the thickness of the soft parts 10 cc of 0.5 per cent novocaine-suprarenin solution will be necessary.

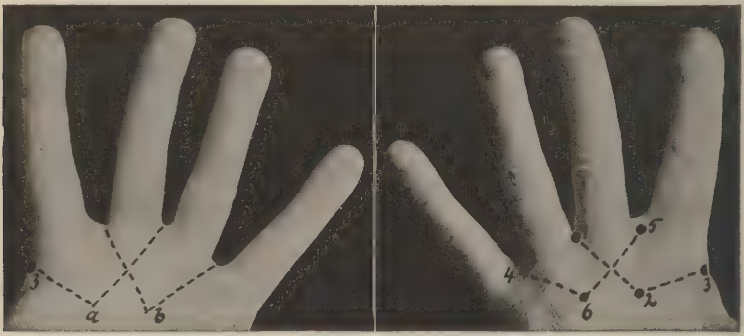

Fig. 193 Fig. 194

Figs. 193 and 194.—Anesthesia of two fingers with part of the hand.

The next step is a subcutaneous injection from points 5 and 7 in the palm toward point *a* and on the back of the hand toward point 6. It is unnecessary to ligate the arm. About 50 cc of 0.5 per cent novocaine-suprarenin solution are necessary. This procedure shows at once that it is possible to make the thenar eminence insensitive without penetrating the sensitive skin of the palm. This method can also be used for anesthesia of the fifth finger and its metacarpal bone.

Anesthesia of Several Fingers and Parts of the Palm (Figs. 193 and 194).—Points 1, 2, 3 are used for anesthesia of the second and third fingers and are marked by wheals. The injection in the interosseous spaces should be made from point 2 toward point *a* and a subcutaneous infiltration is made from points 1 and 3 in the palm toward point *a* and on the back of the hand toward point 2. The points of entrance, 4, 5, 6, are used in the same manner for anesthetizing the fourth and fifth fingers at the same time. If necessary, parts of the palm can be included in the anesthetized area by placing the points of injection 2 or 6 closer to the fingers or the

wrist, as the case may be; 50 cc of 0.5 per cent novocaine-suprarenin solution are necessary

Operations on Soft Parts of the Palm.—The technic of the anesthesia of the thenar and hypothenar eminences by circuminjection has already been described in connection with disarticulation of the thumb. Every other part of the palm can be treated in the same way. The points of entrance (usually two) should always be placed on the side of the hand and on the back of the interdigital folds. For example, we will select a field of operation which is limited to the soft parts of the palm, above the index finger (Figs. 195 and 196). In this case the points of entrance are marked 1 and 2. From both of these points a free injection of 30 to 40 cc of 0.5 per cent novocaine-suprarenin solution is made toward point *a* in

FIG. 195

FIG. 196

FIGS. 195 and 196.—Anesthesia of a part of the palm.

the palm. In case of phlegmon of the hand, injections near the diseased parts must be avoided. Preferably they should be rendered insensitive by plexus anesthesia. Abscesses are opened more quickly and better under ethyl chloride anesthesia, as recommended by Kulenkampff.

Operations on the Soft Parts of the Back of the Hand.—In this region operations are usually aseptic, such as the treating of injuries, extirpation of ganglia, hygromata, and tumors. The field of operation is circuminjected with 0.5 per cent novocaine-suprarenin solution. Fig. 197 shows a number of possibilities for circuminjection. In most cases it will only be necessary to circuminject three sides of the field of operation in a fork-shaped or U-shaped manner, since the innervation to the field of operation is derived exclusively from the arm. A three-sided circuminjection of the field of operation is usually sufficient to produce peripheral anesthesia.

If the circuminjection is first made under the tendons and then subcutaneously, the anesthesia will not be limited to the skin and subcutaneous connective tissue. For aseptic operations on the back of the hand it is, therefore, never necessary to administer a general anesthetic.

Blocking the Ulnar Nerve at the Elbow.—This nerve-blocking was introduced by Krogius and is easily done and very reliable, as can be demonstrated on one's own arm. The nerve which usually lies above the inner condyle of the humerus is plainly felt as it rolls between the fingers, the pressure causing the patient to complain of a peculiar sensation. The nerve is then fixed with the thumb and left index finger and the needle is inserted into it through the subcutaneous cellular tissue and fascia. At the moment when the point of the needle touches the nerve and penetrates it the patient again experiences the same paresthesia as is felt when pressure is made on the nerve, which indicates that the needle is in the proper place for the injection of the anesthetizing solution. It must be remembered that in some few persons, when the forearm is bent, the trunk of the

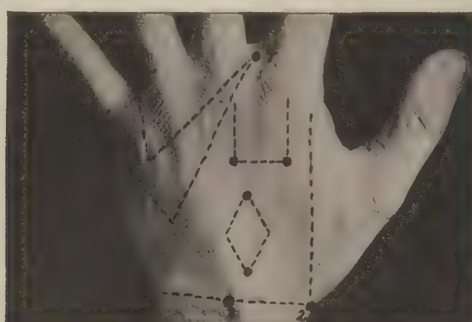

FIG. 197.—Anesthesia of the soft parts of the back of the hand.

ulnar nerve is situated in front of and not behind the inner condyle and only slips behind when the arm is extended; a subcutaneous or subfascial injection in this position will naturally be ineffective. Figs. 198 and 199 show the extent of the anesthesia which, as a rule, occurs immediately after the injection. This shows the adaptability of this form of anesthesia for operations on the fifth finger, the hypothenar eminence, the ulnar edge of the hand, and the fifth metacarpal bone.

For disarticulation of the fifth finger and other operations in this region there is no simpler method of anesthesia. During this operation ligation is necessary and should be applied before the operation to the forearm above the wrist, where it does not annoy the patient.

Anesthesia of the Whole Hand.—The following nerves extend from the forearm to the hand: the ulnar, median, and interosseous, all of which lie in the deep fascia, and the terminal branches of the radial nerve which are placed subcutaneously. Fig. 200 is a cross-section through the forearm just above the wrist. The two arrows indicate the direction in which

FIG. 198

FIG. 199

FIGS. 198 and 199.—Anesthesia following the blocking of the ulnar nerve at the elbow.

the needle should be inserted for blocking the median and ulnar nerves. In order to block the median nerve, a point of entrance (Fig. 201) is marked

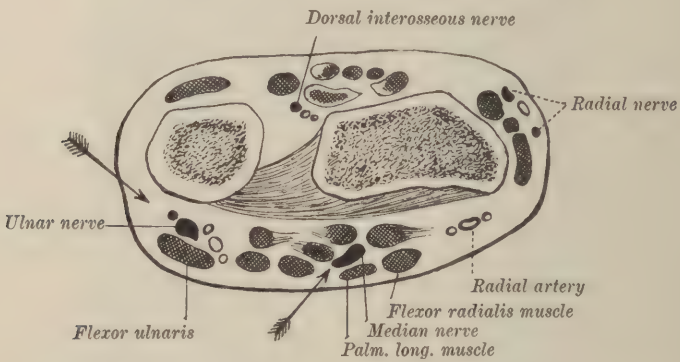

Fig. 200.—Cross-section through the forearm above the wrist-joint.

toward the ulnar side, close to the tendon of the palmaris longus. The needle is inserted through the fascia underlying the tendon mentioned. Search is then made until the point of the needle strikes the nerve trunk.

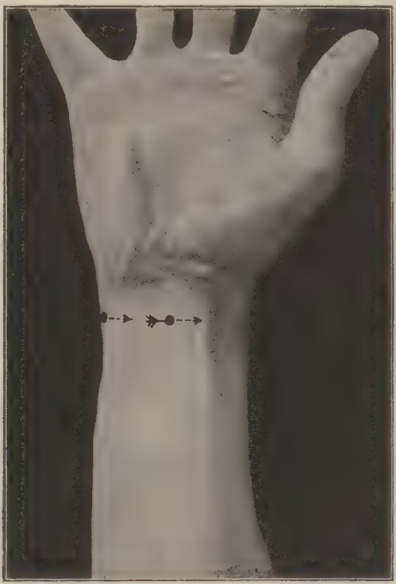

Fig. 201.—Points for injecting the median and ulnar nerves above the wrist-joint.

The patient should be requested to say when radiating paresthetic sensations are felt; 5 cc of 2 per cent novocaine-suprarenin solution are then

injected and 5 cc of the same solution are injected from the ulnar edge of the forearm above the pisiform bone and under the flexor ulnaris. Finally, the subcutaneous cellular tissue around the forearm is infiltrated from the same point and possibly 2 or 3 others, and on the extensor side the subfascial tissue is also infiltrated between the tendons down to the interosseous ligament with 50 to 60 cc of 0.5 per cent novocaine-suprarenin solution. The resulting anesthesia of the whole hand is, as a rule, complete in from ten to fifteen minutes. This method is to be preferred to venous anesthesia of the hand.

Operations on the Forearm.—The skin and subcutaneous connective tissue of the forearm to the lower third is exclusively innervated by long subcutaneous nerves which emerge from the fascia above the elbow (medial, lateral and dorsal antebrachial cutaneous nerves, Fig. 178). Consequently the infiltration of a transverse strip of the subcutaneous cellular tissue of the forearm results in anesthesia extending more or less peripherally from the point of injection, and if the subcutaneous cellular tissue is infiltrated circularly close above or below the elbow with a 0.5 per cent novocaine-suprarenin solution, the anesthesia will extend to the lower third of the forearm in every direction. This method has no more practical value than the more easily accomplished blocking of the individual nerve-trunks mentioned. Conduction anesthesia of the lateral antebrachial cutaneous nerve, as it emerges from above the elbow on the lateral edge of the biceps and passes into the subcutaneous cellular tissue, has a historical value, for Corning, in 1885, observed for the first time in a human being the peripheral extension of skin anesthesia following an injection of cocaine made at the point of emergence of this nerve.

In anesthetizing for operations the following observations should be made: Operations on the upper two-thirds of the forearm, limited to the skin and the subcutaneous cellular tissues, are circuminjected with a 0.5 per cent novocaine-suprarenin solution in a U-shaped manner (Fig. 197). The innervation from one direction of this region makes circuminjection unnecessary. In the lower third of the forearm the U-shaped circuminjection should always be made subfascially, because of the location of the nerves (Fig. 178). This fact might possibly frustrate the result of a purely subcutaneous circuminjection. All circumscribed tumors can be circuminjected according to Fig. 30 (page 192) in a pyramidal or cup-shaped manner. Large anesthetic areas on the extensor surface of the lower third of the forearm can be obtained in the following manner (Fig. 202): Two points of entrance are marked at the same height on the extensor side of the forearm at a point corresponding to the palpable edge of the ulna and radius. Between these points all the soft parts of the extensor side, first the muscles and then the subcutaneous cellular tissue, are infiltrated transversely to the long axis of the arm with 40 to 50 cc of 0.5 novocaine-suprarenin solution. From both these points of injection strips should be injected subcutaneously to the wrist and, when necessary, to the fingers, for which purpose more points of entrance may be required. It is unnecessary to ligate the arm during the operation. This method

can be used for the treatment of any injury to the soft parts and for extirpation of tumors, hygromata, and tendon-sheath tuberculosis in this region.

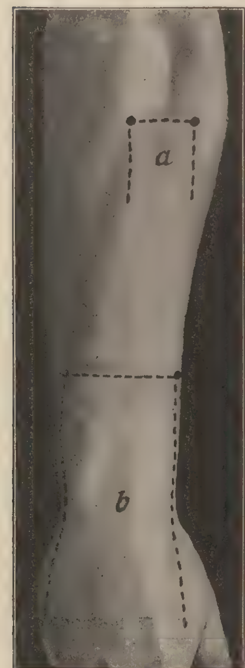

FIG. 202. — U-shaped injection of the forearm and back of hand.

A corresponding method on the lower half of the flexor side of the forearm is carried out a little differently on account of the ulnar and median nerves. The two points of entrance are again marked on the side of the forearm and are connected by infiltration across the forearm, at first close to the bone and interosseous ligament and then by infiltration of the subcutaneous cellular tissue. It is unnecessary to infiltrate all the muscles, in fact that is hardly possible, and does not result in a blocking of the ulnar and median nerves. If the field of operation lies within the area supplied by the ulnar nerve, this nerve should be blocked at the elbow (page 374), and if it lies in the territory of the median nerve this nerve should be sought at the upper end of the incision and blocked by intraneural injection, just as soon as it is exposed, during the operation. It will be necessary to ligate the arm during this operation and, therefore, anyone who is familar with plexus anesthesia, will prefer it in this case. Phlegmons, bone operations, extensive operations on the soft parts of the upper half of the forearm, and amputations are performed under plexus anesthesia.

Operations on the Elbow.—A U-shaped infiltration of 40 cc of 0.5 per cent novocaine-suprarenin solution into the subcutaneous cellular tissue of the back of the elbow from two points of entrance (Fig. 203, 1 and 2) will be sufficient for extirpation of an olecranon bursa. For suturing a fractured olecranon process, two extra points of injection should be marked (Fig. 197, 3 and 4). An injection of 20 cc

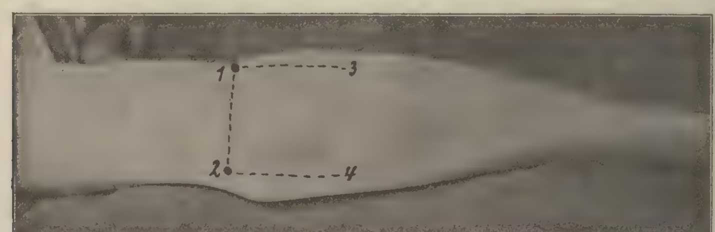

FIG. 203.—Horseshoe shape injection of the elbow-joint.

of 0.5 per cent novocaine-suprarenin solution is first made into the elbow-joint beneath the outer or inner condyle. From each of the points 1 and 2,

10 cc of the solution are injected under the triceps tendon and from each of the points 3 and 4, 10 cc are injected into the inner and outer muscles covering the ulna. Finally a U-shaped subcutaneous injection is made.

In order to perform an aseptic arthrotomy (for removal of loose bodies in joints) 20 cc of a 0.5 per cent novocaine-suprarenin solution are injected into the joint and the capsule and the subcutaneous cellular tissue is infiltrated in the line of incision. Resections and disarticulations require the plexus anesthesia.

Operations on the Upper Arm.—Anesthetizing local injections only must be considered for superficial operative procedures. Simple subcutaneous circuminjections are not always successful, owing to the numerous and irregular points of emergence of the nerves (Fig. 178). Therefore, it is always necessary to make a complete pyramidal or encasing circuminjection of the field of operation (page 198). In order to make the skin of the entire outer surface of the upper arm sufficiently insensitive for the removal of Thiersch's grafts or Kraus's skin flap, the entire subcutaneous cellular tissue should be infiltrated in layers as far as it is necessary with a 0.5 per cent novocaine-suprarenin solution in the same manner as will be described for the thigh. Complicated operations on the upper arm, bone operations and dislocations should be performed under plexus anesthesia.

Operations in the Shoulder Region.—Large lipomata of the shoulder region are very easily removed under local anesthesia. A number of points of entrance should be marked around the tumor. From these points the whole base of the tumor is systematically circuminjected with long needles. Finally the points of entrance are joined by subcutaneous injection strips; 0.5 novocaine-suprarenin solution is the proper anesthetic to be used. Large lipomata will frequently require from 200 to 250 cc of the solution. Operations on the shoulder-joint are best performed under plexus anesthesia, according to the method of Kulenkampff. Methods have already been mentioned for disarticulations of the shoulder-joint. For this purpose the plexus must be blocked and besides this the subcutaneous cellular tissue at the base of the limb (*i. e.*, from the acromion process across the axilla) must be circularly infiltrated with a 0.5 per cent novocaine-suprarenin solution. Under local anesthesia and by the anterior incision of Langenbeck the author has often resected a joint and reduced by operation irreducible axillary dislocations of the humerus and twice has operated for fractures of the upper end of the humerus. Besides blocking the brachial plexus the line of incision is freely infiltrated with 0.5 per cent novocaine-suprarenin solution, whereby the bleeding is decidedly lessened. A shoulder-joint may be resected either by a posterior incision, according to Kocher, or by the deltoid incision, which is preferred in complicated cases. For the last mentioned incision the same method is used as described for disarticulations. For Kocher's incision it will probably be necessary to block the lower branches of the cervical plexus according to Kappis, or from the side (page 273) by infiltration toward the transverse processes of the cervical vertebræ. For all these operations we can certainly dispense with general anesthesia. For performing minor

operations on the clavicle, for example, the chiseling of a disturbing callus (Fig. 204), the entire bone must be circuminjected from two points of entrance in a trough-like manner, according to the diagram shown in Fig. 39, (page 199).

Fig. 204.—Trough-shape circuminjection of the clavicle.

OPERATIONS ABOUT THE LOWER EXTREMITY.

Sensory Innervation.—The foot and leg are supplied by the sciatic and anticrural nerves entirely, while a great number of other nerves are concerned in the sensory innervation of the upper thigh, some of which reach the thigh directly from the pelvis. The most important of these are the obturator posterior and lateral femoral cutaneous, while the others, the iliohypogastric, ilioinguinal, genitocrural, and the superior gluteal, supply the innervation of the skin at the base of the thigh.

Figs. 205 and 206 schematically show the points of exit of the sensory nerves and their peripheral distribution to the lower extremity.

Conduction Anesthesia of the Thigh.—The conditions for anesthesia of the lower extremity by central conduction anesthesia are much more unfavorable than they are for the arm, for in the arm the main nerve trunks originating from the cervical plexus form a single cord, while in the lower extremity at least five nerves must be blocked separately. Blocking the lateral cutaneous femoral, which innervates the skin of the upper thigh, was described by Nyström in 1909. This nerve emerges close beside and medial to the anterior-superior spine of the ilium under Poupart's ligament (Fig. 207). Running for a short distance downward under the fascia lata, it penetrates it in one or more places, and thus reaches the subcutaneous cellular tissue and the skin. In order to block the trunk of the nerve, Laewen suggests that a point of entrance be marked two

finger-breadths inward and downward from the anterior-superior spine of the ilium (Fig. 208). From this point an injection is made transversely

Fig. 205

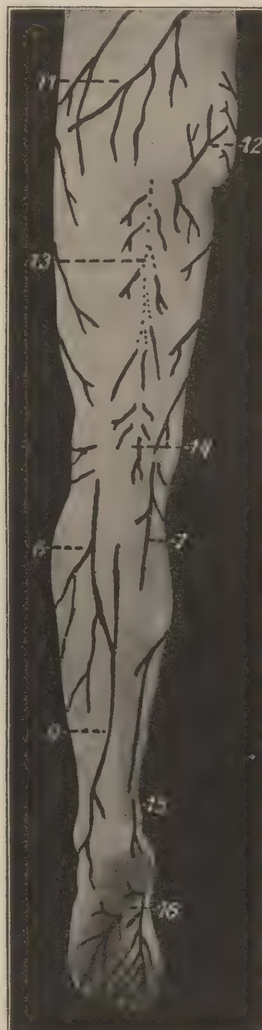

Fig. 206

Figs. 205 and 206.—Scheme of sensory innervation of the lower extremity: 1, iliohypogastric; 2, lateral femoral cutaneous; 3, lumboinguinal; 4, anterior femoral cutaneous; 5, obturator; 6, lateral dural cutaneous; 7, saphenous; 8, superficial peroneal; 9, sural; 10, deep peroneal; 11, superior gluteal; 12, inferior gluteal; 13, posterior femoral cutaneous; 14, medial sural cutaneous; 15, tibial cutaneous branch; 16, tibial.

outward as well as below and beyond the spine. Two injections consisting of 2.5 cc of 2 per cent novocaine-suprarenin solution each are made, one

under the fascia and the other under the skin. The nerve will then be blocked. Nyström advised this method for the removal of epithelial grafts from the outer side of the upper thigh. Unfortunatelyy it is unreliable, a fact which Laewen has also noted, because the extent of skin anesthesia resulting from the injection is so variable and often very small. Laewen therefore advises that besides the nerve mentioned the anterior crural nerve should also be blocked. This nerve lies a little outward from the femoral artery and is separated from it by a strip of fascia (ileopec-

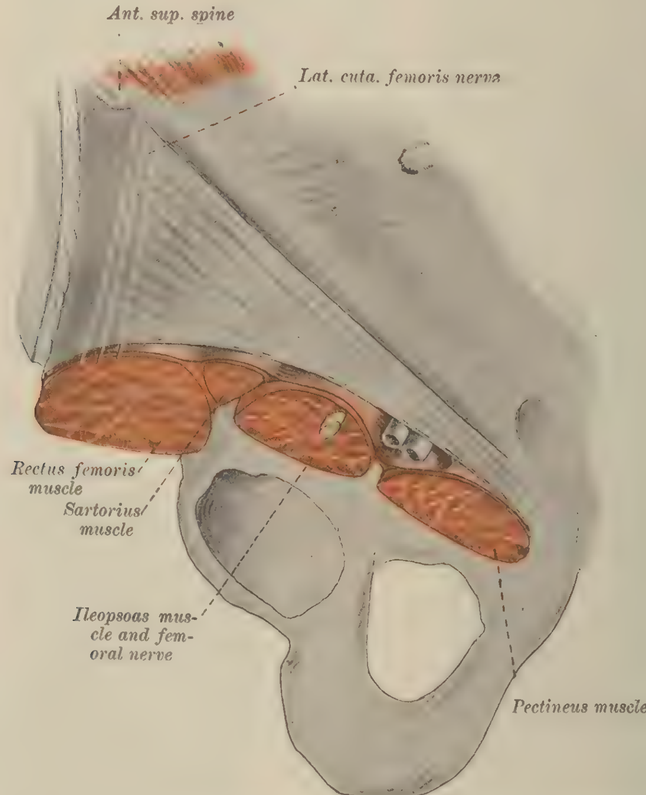

FIG. 207.—Cross-section through the thigh below Poupart's ligament.

tineal ligament) and, as a rule, by a layer of iliopsoas muscle. It frequently does not lie close under the fascia lata, but deeper in a connective tissue septum of the muscle mentioned. These relations are shown in Fig. 207. Laewen therefore gives the following directions: The pulse of the femoral artery should be palpated under Poupart's ligament. The fingers of the left hand should remain upon the artery, so as to be constantly assured of its position. A point of entrance is marked just under Poupart's ligament about 1 to 1.5 cm. outward from the spot where the pulse of the

artery is palpable (Fig. 208). From this point a fine needle is inserted perpendicularly and the fascia lata, which is easily felt, is penetrated; 5 cc of 2 per cent novocaine-suprarenin solution should be injected, inserting the needle 0.5 to 1 cm. deeper during the injection. To this should be added that the point of the needle must touch the nerve.

At the moment when the nerve is touched a very characteristic contraction of the muscles of the thigh is noted, and if the injection is then made, the blocking will be completed in a few minutes. The most striking feature is the motor paralysis of the quadriceps femoris muscle. Keppler also strongly advises that the injection be not made until the point of the needle coming in contact with the nerve gives rise to characteristic paresthesia in the femoral region. While the blocking of the crural nerve alone

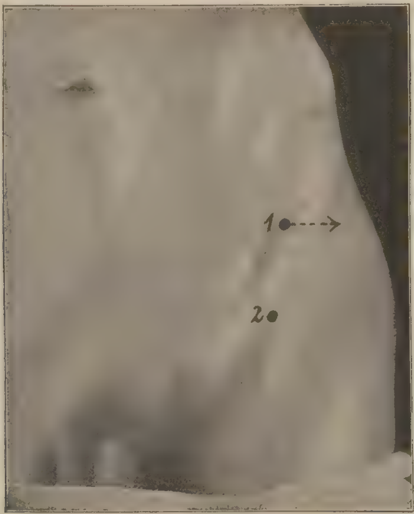

Fig. 208.—Points for injection. 1, for the lateral femoral cutaneous; 2, for the femoral.

has as little practical significance as the blocking of the lateral femoral cutaneous alone, nevertheless the blocking of both nerves conjointly furnishes a very large anesthetic field which is very constant in extent. The limit of the field of anesthesia is shown by Figs. 209 and 210.

Laewen recommends his method especially for removal of epithelial grafts, for which purpose it gives surprisingly good results. In this manner he was also able to remove painlessly a large lipoma from the rectus femoris muscle. The simultaneous blocking of the anterior crural nerve and the lateral femoral cutaneous is a simple method, and one that can be generally used for all suitable cases. On the other hand, those nerves which emerge from the pelvis and are distributed to the thigh are reached with difficulty.

Crile exposes the sciatic nerve and blocks it by endoneural injection (page 159). The blocking of this nerve through the skin is not so difficult

as was formerly thought. The nerve trunk lies deeply seated in the gluteal region, slightly median to the middle of the line joining the trochanter major, and the tuberosity of the ischium. Laewen, to whom special credit is due for his thorough investigations, aims to palpate the nerve in this spot in lean persons, and injects from two points of entrance, one of which is situated 2 cm. outward from the tuberosity of the ischium, the other 3 cm. inward from the trochanter.

Fig. 209

Fig. 210

Figs. 209 and 210.—Extent of anesthesia after blocking the lateral femoral cutaneous and femoral nerves.

Perthes aims to reach the nerve trunk in the gluteal fold. Jassenetzki-Woino, Keppler and Babitizki aim to reach the nerve higher up before it gives off the lesser sciatic, where it lies spread out flat on the lower ascending border of the great sacro-sciatic foramen. With the help of Haertel's anatomical sketch, the injection of the sciatic nerve at this point has become a rather certain procedure, which is to be preferred to its injection more distally. Fig. 211 shows Haertel's method of locating the point of injection and the direction of the lateral border of the sacro-sciatic foramen. Figs. 211 and 212 show the markings on the surface of the body. When the point of puncture is located approximately with the help of this diagram, it is easy to feel the lateral border of the foramen with the needle and thus find

the nerve and with the point of the needle to excite the characteristic paresthetic sensations which are felt in the external genitals (pudendic nerve), in the gluteal region and upper thigh or in the lower thigh and foot depending on whether the nerve touched is the spina ossis ischii or more laterally. The technic of this method of blocking is as follows: The patient is placed on the abdomen or the well side. In muscular or fat persons the longest needle is necessary (No. 7). The point of puncture

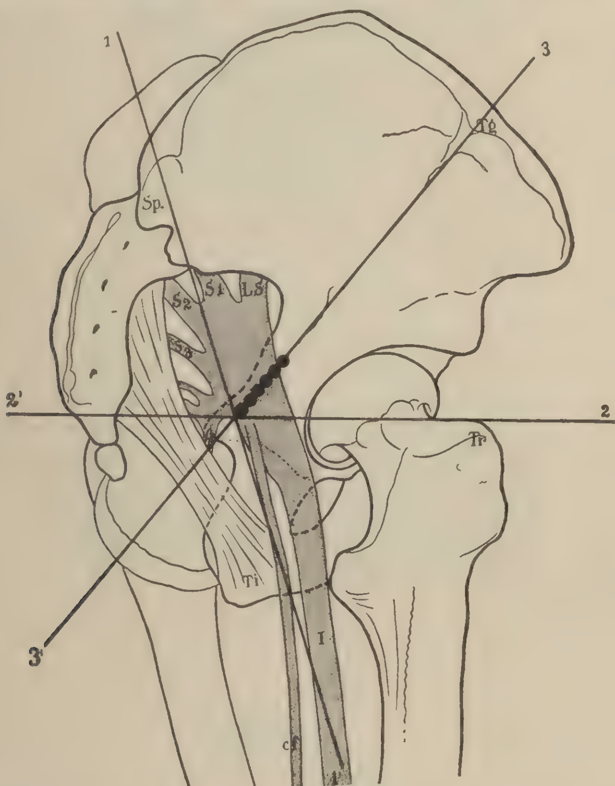

Fig. 211.—Puncture of the sciatic nerve. (After Härtel.) *Line* 1-1′ extends from the posterior superior spine of the ilium to the lateral border of the tuberosity of the ischium. *Line* 2-2′ extends horizontally through the point of the trochanter. *Line* 3-3′ extends from the anterior gluteal tubercle through the crossing of lines 1-1′, and 2-2′ and indicates the point of puncture. It follows the direction of the lateral border of the great sciatic foramen.

is located and marked by a wheal through which the needle is introduced and the lateral border of the foramen searched for. When paresthetic sensations are felt by the patient indicating that the needle is in contact with the nerve, a 2 per cent novocaine-suprarenin solution is injected, (20 to 25 cc altogether) at different points on a line parallel with the lateral border of the foramen. The waiting time for complete anesthesia is often twenty minutes or longer.

Perthes and Keppler recommend that the obturator nerve be sought

at the point where it escapes from the obturator foramen. According to Keppler, the point of entrance of the needle lies a thumb's breadth below the spine of the pubis. The needle is introduced down to the bone and is

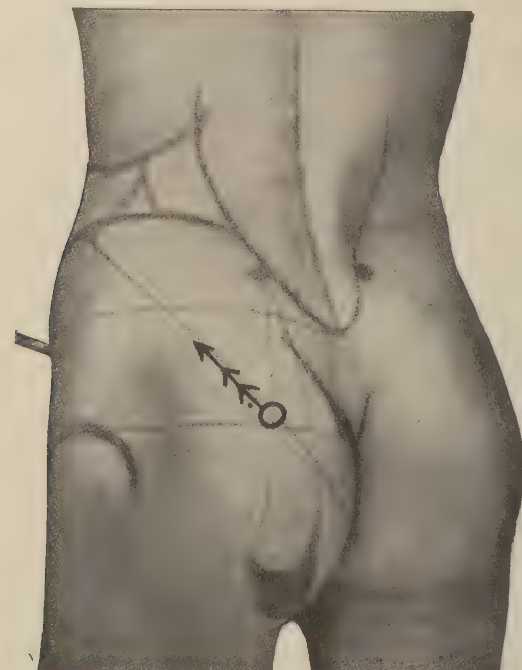

Fig. 212.—Puncture of the sciatic nerve. (After Härtel.)

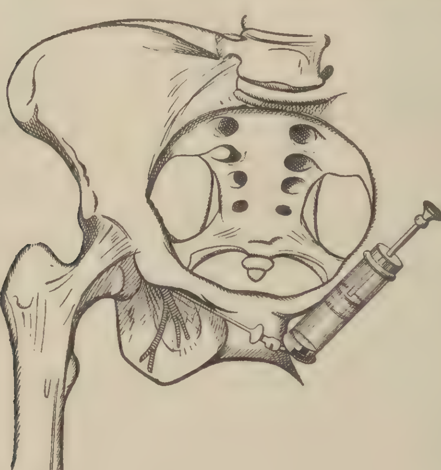

Fig. 213.—Puncture of the obturator nerve. (After Kippler.)

carried in touch with the bone along the lower border of the horizontal ramus of the pubis upward and outward until it strikes bony resistance at the point of junction of the pubes and the ischium. The nerve trunk lies at this point and when touched with Perthes' electric needle, contractions of the adductor muscle are produced (Fig. 213). For operations on the foot, blocking of the sciatic nerve is sufficient if the terminal distribution of the saphenous nerve is interrupted by the subcutaneous infiltration of a narrow strip above the inner malleolus. Operations on the lower leg require blocking of both the sciatic and the anterior crural nerves. Operations on the knee and thigh require blocking of all four nerves. The anesthesia then extends above the middle of the thigh. The experience of Laewen, Perthes, Keppler, Wiedhopf and others show that with a little patience, blocking is usually successful and very satisfactory results may be obtained by this method and that the dose of novocaine remains within the normal limits. The large doses originally used by Laewen are not necessary. As has been mentioned on page 157, Hohmeier and Sievert recently have again attempted the method of Hölscher which consists not in blocking the nerve trunks but in the attempt to produce a conduction anesthesia by a complete infiltration of a transverse section of the thigh. The method of Hohmeier seems to be one of simple local infiltration anesthesia. The author believes that it is not possible to completely infiltrate a transverse section of a large extremity and that the use of a 0.5 per cent novocaine-suprarenin solution in the manner of Hohmeier will not successfully block nerve-trunks. On the other hand, Sievers has materially increased the effect of the anesthetizing fluid and has prevented its escape above and below in the direction of the least resistance by placing two elastic constrictors about the thigh a short distance apart and infiltrating the intervening narrow transverse section. In 16 of 18 cases anesthesia of the distal portion of the extremity was obtained. The leg, made bloodless for this purpose by bandaging or elevating it, is constricted a hand's breadth above the knee with an elastic constrictor. Immediately above this is placed a second elastic constrictor. The opposed edges of the constrictors are turned back slightly so as to expose a narrow strip of protruding skin. From several points of entrance the subcutaneous tissue and the musculature down to the bone are infiltrated with a 0.5 to 1 per cent novocaine-suprarenin solution without regard to the location of the large nerve trunks. At the end of ten minutes, the proximal constrictor should be loosened somewhat, but be left so that it still constricts slightly. The disagreeableness of the constriction to the patient does not seem to have been entirely abated by this means, for Sievers recommends in sensitive patients the use of light narcosis up to the time when the tightly constricted bands can be changed for ones which simply interrupt the blood stream. Haertel recommends this method in war wounds of the lower extremities. Corning described the "incarceration" of cocaine solution between two elastic bandages in 1885. The author cannot fail to remark that all of these methods of producing anesthesia of the leg on the whole are too circumstantial and time-consuming to successfully compete with narcosis,

and that in cases where it is desired or necessary to avoid the latter, lumbar anesthesia is to be preferred. [The entire lower extremity can be rendered anesthetic by blocking the great sciatic at its exit from the pelvis, the lesser sciatic at the lower border of the gluteal fold, the external cutaneous near the anterior-superior spine of the ilium, the anterior crural beneath Poupart's ligament, and the obturator, should it be necessary, at its point of exit from the pelvis at the upper and outer angle of the obturator foramen. The exact method of blocking these several nerves is fully described elsewhere. Under anesthesia thus produced, operations and amputations at any point on the leg or thigh may be painlessly performed and the method is particularly advantageous in amputations for senile gangrene in the aged and in amputations for crushing injuries in the presence of shock.—Ed.]

Anesthesia of the Toe, According to Oberst.—The method is the same as used for the fingers (Figs. 214 and 215). On the great toe two

Fig. 214

Fig. 215

Figs. 214 and 215.—Anesthesia of the great toe. (After Oberst.)

points of entrance are marked on the edge a little more toward the extensor side. From these points injections are made under the skin of the flexor side, as indicated by the dotted line. On account of the prominence formed by the extensor tendons, it is more convenient to make the injection under the skin of the extensor side from a third point, situated in the middle of the extensor side. 3 to 4 cc of 2 per cent novocaine-suprarenin solution are necessary. For the other toes the points are marked in the interdigital spaces as in Fig. 216.

Disarticulation of the Great Toe.—Hallux Valgus Operation (Fig. 216).—There are three points of entrance to be marked; the first is in the median line on the border of the foot, the second on the back of the foot over the first interosseous space; the third in the first interdigital fold. The first injection is made into the interosseous space and is carried out just as in the hand. The needle is inserted and infiltration is made through the interosseous space, until the applied finger feels the point of the needle under the the skin of the sole. Then follows the subcutaneous injection

from points 1 and 3 in the direction of the dotted line: 40 to 50 cc of 0.5 per cent novocaine-suprarenin solution will be necessary. The operator should wait until the whole toe becomes insensitive. Ligation is not necessary for disarticulation.

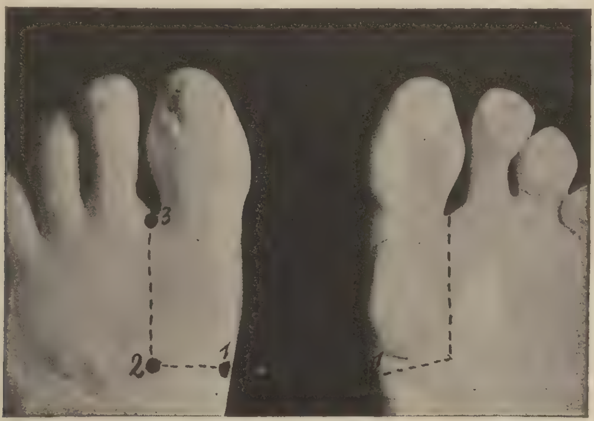

Fig. 216.—Disarticulation of the great toe. Hallux valgus operations.

Fig. 217.—Disarticulation of the third toe.

Disarticulation of the Third Toe.—Operations on the Third Metatarsal Bone (Fig. 217).—Four wheals are placed as in the corresponding operation

on the hand; two lie on the extensor side of the interdigital folds, two on the back of the foot over the second and third interosseous spaces. The needle is pushed forward from points 1 and 2, injection being made into the spaces between the bones until the needle is felt under the skin of the sole at point *a*. Then follow injections from points 3 and 4 under the skin of the sole toward point *a*, and under the skin of the back of the foot toward points 1 and 2. Finally, subcutaneous injections are made between points 1 and 2; 50 cc of 0.5 per cent novocaine-suprarenin solution are necessary.

Operations on the Back of the Foot.—The technic of the anesthesia is the same for the back of the hand. There is nothing to add to that which has already been stated on page 373.

Tenotomy of the Tendo Achillis (Fig. 218).—A point of entrance is marked to the right and left of the tendo Achillis, and the field of operation is infiltrated in a trough-like manner, according to Fig. 38 (page 198). In adults and older children it is possible to perform operations on the tendo Achillis under local anesthesia. These cases are, of course, always exceptional, as the other therapeutic measures associated with tenotomy usually require further anesthesia.

Anesthesia of the Entire Foot.—For extensive operations on the bones and soft parts of the foot always observe the following directions: Five nerves pass from the calf of the leg to the foot, the tibial, saphenous, sural, and superficial and deep peroneal (see Figs. 205 and 206). Blocking the tibial behind the internal malleolus produces anesthesia of the region designated in Fig. 219 and 220, and the blocking of the deep peroneal is shown in Fig. 224. If an anesthetic is subcutaneously injected in a transverse strip above the internal malleolus, the terminal branches of the saphenous nerve will be blocked, and anesthesia of the skin area, shown in Fig. 221, is obtained. In the same manner a strip injected above the outer malleolus will block the superficial peroneal and sural, and anesthesia of the area shown in Figs. 222 and 223 is obtained.

It is very easy to block the tibial at the designated spot. Fig. 225 shows a cross-section through the lower leg just above the ankle. The arrows indicate the direction taken by the needle in reaching the nerve trunks. The point of entrance lies high up, where the inner malleolus is thickest, about 1 cc distant from the tendo Achillis. From this point the needle is inserted directly forward until the posterior surface of the tibia is felt. Continued search must be made until the patient, who has been previously instructed, announces that paresthesia is felt, radiating to the toes. If blood flows from the needle, it must be drawn back a little and reinserted more to the side. As soon as the paresthesia is felt, 5 cc of 2 per cent novocaine-suprarenin solution are injected and after a few minutes the blocking of the nerves will be noted.

The method is as follows: several points of entrance are marked—one at the point mentioned, behind the inner malleolus; the others, usually four, are marked at the same height all around the lower leg. The tibialis is blocked by an injection of 5 cc of 2 per cent novocaine-suprarenin

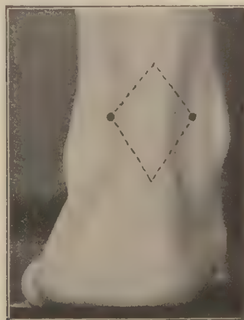

FIG. 218.—Tenotomy of the tendo Achillis.

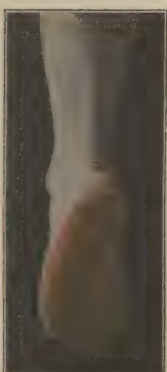

FIG. 219

FIG. 220

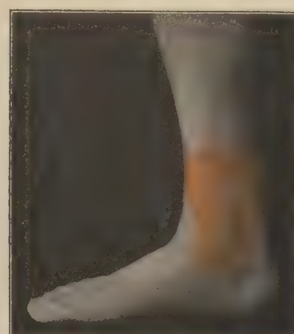

FIG. 221

FIG. 222

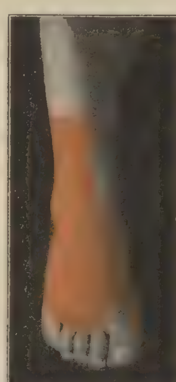

FIG. 223

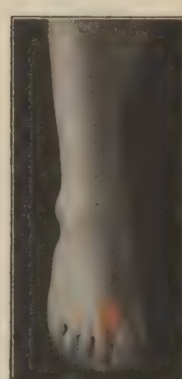

FIG. 224

FIGS. 218 to 224.—Anesthesia of foot following conduction anesthesia. Figs. 219 and 220, tibial is blocked behind the inner malleolus; Fig. 221, subcutaneous injection of a semicircle above the inner malleolus; Figs. 222 and 223, subcutaneous injection of a semicircle above the outer malleolus; Fig. 224, injection of the deep peroneal nerve.

solution as described above, and the subcutaneous cellular tissue of the lower leg is then infiltrated from the other points of entrance as is also the tissue lying between the tendons and the anterior surface of the tibia. The latter is done in order to block the deep peroneal. Finally the fat which lies behind the tendo Achillis is infiltrated with 50 to 75 cc of 0.5 per cent novocaine-suprarenin solution.

This excellent method is used in performing operations on the sole of the foot and the metatarsal and tarsal bones. We have performed amputations according to the methods of Lisfranc, Chopart, Pirogoff, disarticulations at the ankle-joint, resections in the region of the tarsus and opera-

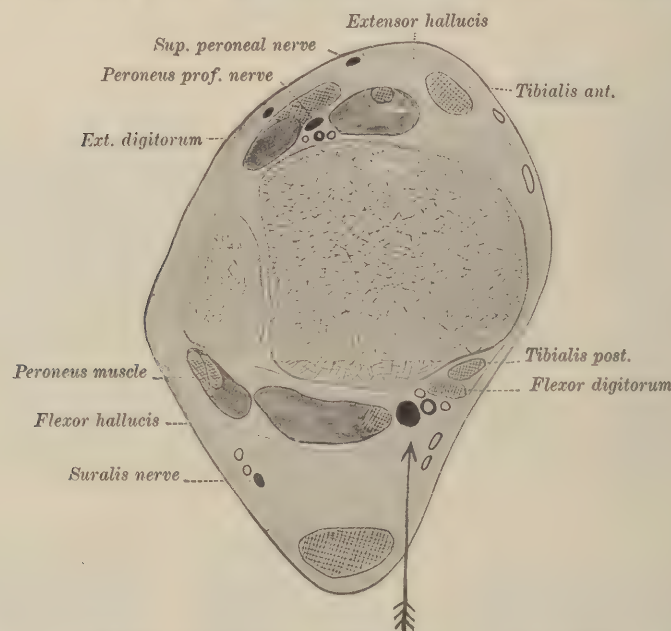

FIG. 225.—Cross-section of the leg above the ankle-joint. (After Braun.) The arrow indicates the method of injecting the tibial nerve.

tions for the correction of club-foot in older children. This method, which is naturally contraindicated in cases of phlegmon, has never failed us. For amputation it is not necessary to ligate the extremity, because the arteries bleed so little under the influence of the suprarenin.

Operations on the Leg.—It is necessary to thoroughly inject under and around the field of operation of the leg, even if it be superficial and confined to the skin and subcutaneous cellular tissue. A simple subcutaneous circuminjection is unreliable. The anastomotic peroneal nerve and the saphenous nerve which supply the skin of the leg are easily blocked, the former in the popliteal space, beside the head of the fibula, the latter by infiltrating a strip of the subcutaneous cellular tissue which extends

laterally from the tuberosity of the tibia to the middle of the calf of the leg. A 0.5 per cent novocaine-suprarenin solution is used. This blocking has little practical value because the blocking of the third nerve supplying the tibia, namely, the tibial, in the popliteal space, is unreliable and difficult, and the blocking of the two first-named nerves alone only renders a small area insensitive. Bier's venous anesthesia (page 169) is suitable for complicated aseptic operations and amputations of the leg.

Operations About the Knee.—For anesthesia of a prepatellar bursa, four points of entrance must be marked, situated as shown in Fig. 226. A subcutaneous injection alone in the direction of the dotted line would not be sufficient, so before making this injection it will be necessary to push the needle forward from each point of entrance and infiltrate in various directions to the edge of the patella; or, if this is not possible on account of the size of the tumor, the capsule of the knee-joint must be

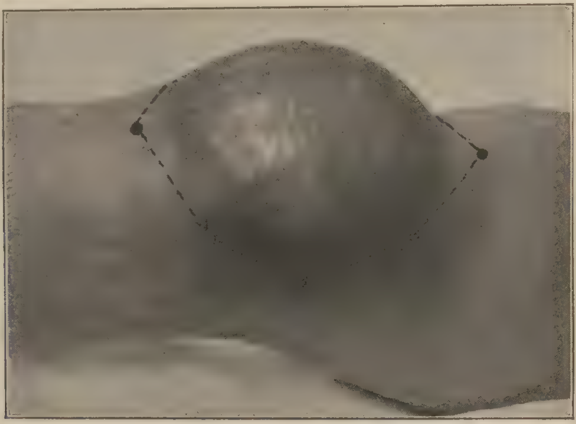

Fig. 226.—Anesthesia for housemaid's knee.

infiltrated from the side and the quadriceps from above; 75 to 100 cc of 0.5 per cent novocaine-suprarenin solution will be necessary. Extirpation of the bursa in aseptic or slightly infected cases never requires a general anesthetic. The use of local anesthesia, however, should be avoided in a perforated bursa with a phlegmonous condition of the surrounding parts.

Ganglia in the Popliteal Space.—Ganglia should always be extirpated under local anesthesia. The tumor must be carefully circuminjected with a 0.5 per cent novocaine-suprarenin solution from four points of entrance. At first the injection should be very deep and then subcutaneous. If during the operation one of the large nerve trunks should come into view, it must be blocked by an endoneural injection of novocaine-suprarenin solution.

Operations on the Knee-joint.—Anesthesia for aspiration of the knee-joint is carried out according to the rules given on page 195. The synovial

membrane is very quickly made insensitive by filling the joint with a 0.5 per cent novocaine-suprarenin solution, which also relieves the contractions induced by the pain. For cases of erosion of the joint or where adhesions exist within the joint, this is not a suitable method. On the other hand, in performing aseptic arthrotomies of the knee-joint for movable cartilages and for meniscus operations, local anesthesia is most suitable. The joint is filled with 20 cc of 0.5 per cent novocaine-suprarenin solution and from two points of entrance (Fig. 227, 1 and 2) the

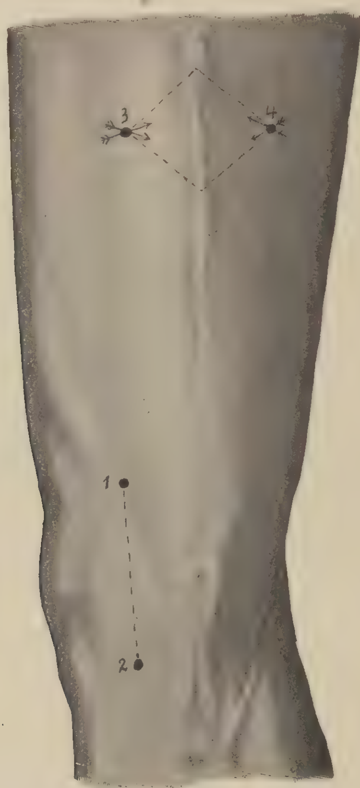

Fig. 227.—1 and 2, arthrotomy of the knee-joint; 3 and 4, resection of the saphenous vein.

joint capsule and subcutaneous cellular tissue are infiltrated in the line of incision (according to Fig. 34, page 194) with the same solution. The operations are always painless, even if it is necessary to open the joint wide.

The author has frequently sutured fractures of the patella under local anesthesia. The points of entrance are practically the same as for prepatellar bursæ (Fig. 226) only the lateral points lie a little farther back. As much of a 0.5 per cent novocaine-suprarenin solution is injected into the joint as it will hold without causing too much pressure and the fluid is

distributed by gentle flexion and extension movements. This causes a part of the fluid to flow between the fractured parts of the patella, producing an anesthetic effect similar to that in hollow bones (page 394). Finally the joint capsule and the subcutaneous cellular tissue are infiltrated in the direction of the dotted line (Fig. 227). For this operation 100 to 150 cc of 0.5 per cent novocaine-suprarenin solution are necessary. In most cases this operation is painless. Resections of the knee-joint are better performed under venous anesthesia.

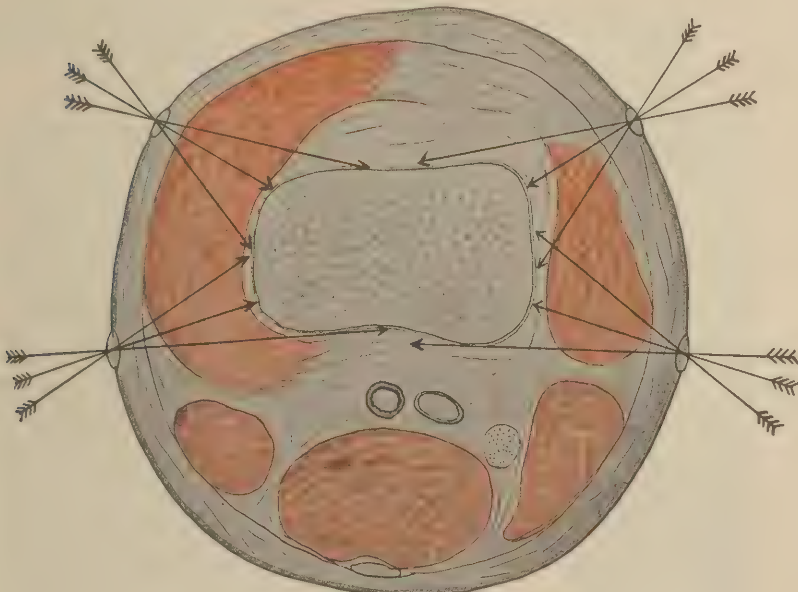

FIG. 228.—Supracondylar osteotomy of the femur.

Supracondylar Osteotomy of the Femur.—The operation for genu valgum (unilateral and bilateral) has often been performed by the author under local anesthesia. Four points of entrance are marked as indicated in Fig. 228. From these points the needle is directed to the bone, passing in front of and behind the bone during the process of injection. The infiltration is only made immediately around the bone at the place where the osteotomy is to be performed. The muscles need not be infiltrated. For this 100 cc of 0.5 per cent novocaine-suprarenin are used. After this has been done, two more points are marked at the ends of the incision to be made, and from them the line is infiltrated to the bone (Fig. 36, page 196). The bone can then be exposed in the usual manner and severed partly by aid of the chisel and the remainder by breaking. The patient must be prepared for this latter act so that he will not be frightened by the cracking of the bone.

Operations on the Soft Parts About the Femur.—Aseptic fields of operation of almost any size can be rendered insensitive by pyramidal, trough-shaped or similar forms of circuminjection, but the simple subcutaneous circuminjection may fail even in very superficial operations on account of the numerous points of exit of the nerves (Figs. 205 and 206).

Operations on the Saphenous Vein.—If only a narrow anesthetized zone is necessary, as is often the case in the ligation of vessels or for the inducing of venous anesthesia, then the infiltration should be made in the line of incision. A wheal should mark each end of the proposed incision and 0.5 per cent novocaine-suprarenin solution should be injected into the line of incision under and beside the vein, and the points of entrance should be joined by a subcutaneously injected strip. If a portion of the vein is to

FIG. 229.—Injection for removing Thiersch grafts.

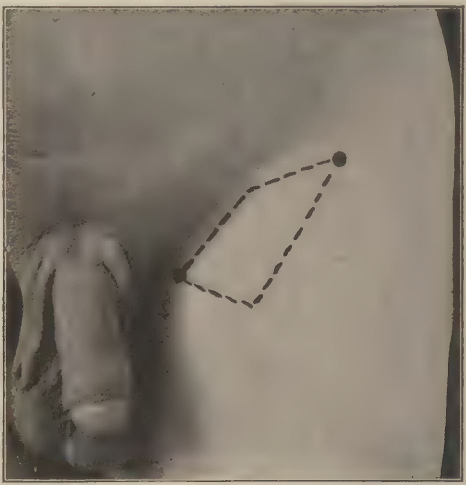

FIG. 230.—Circuminjection of the inguinal region.

be resected according to the method of Trendelenburg, it will be necessary, in order to gain a larger anesthetized field, to make a rhombic infiltration at first under and around the vein, and then a subcutaneous one. Fig. 227 illustrates this method at the spot where varicose veins should always be resected, that is at the upper end of the vein, where it enters the femoral. The technic of anesthesia is the same as that just described.

For the removal of long Thiersch epithelial grafts it is advisable to infiltrate the entire outer surface of the thigh subcutaneously with 0.5 per cent novocaine-suprarenin solution. For this purpose a number of points of entrance are marked in the order shown in Fig. 229, and injection of 0.5 per cent novocaine-suprarenin solution is made from each point in various directions and an even distribution of the solution into the subcutaneous cellular tissue can be obtained by gentle massage. Anesthesia

for the removal of skin or fascial grafts may likewise be produced by blocking the anterior crural and the external cutaneous nerves.

The extirpation of lymphomata of the inguinal and femoral regions can very easily be made painless by circuminjecting the tumor with 0.5 per cent novocaine-suprarenin solution in some manner such manner as indicated in Fig. 230. The needle should be inserted from all sides, pass under the tumor, and should penetrate the region of the fossa ovalis below and also laterally under the fascia of the pectineus muscle and the rectus femoris and above under Poupart's ligament. For the curettement of

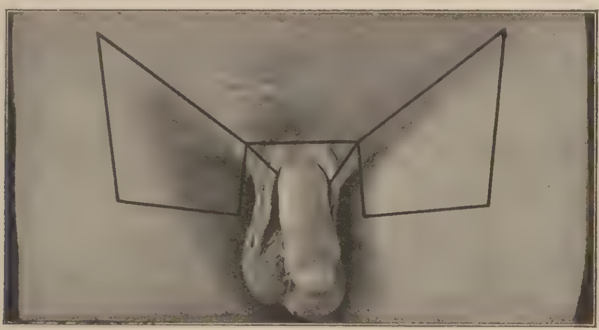

FIG. 231.—Circuminjection for amputation of penis with removal of glands.

diseased lymph glands the same method is necessary. For bilateral removal of all the fatty tissues with the glands, in the groin, use local anesthesia and circuminject in the manner shown in Fig. 231. It is also necessary to make a subfascial injection, especially under the fascia of the external oblique muscle in the region of the skin overlying Poupart's ligament.

The diagram illustrates the manner in which a circuminjection around the root of the penis amputation (page 339) can be added. For such extensive anesthesia not less than 200 cc of 0.5 per cent novocaine-suprarenin solution will be required.

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